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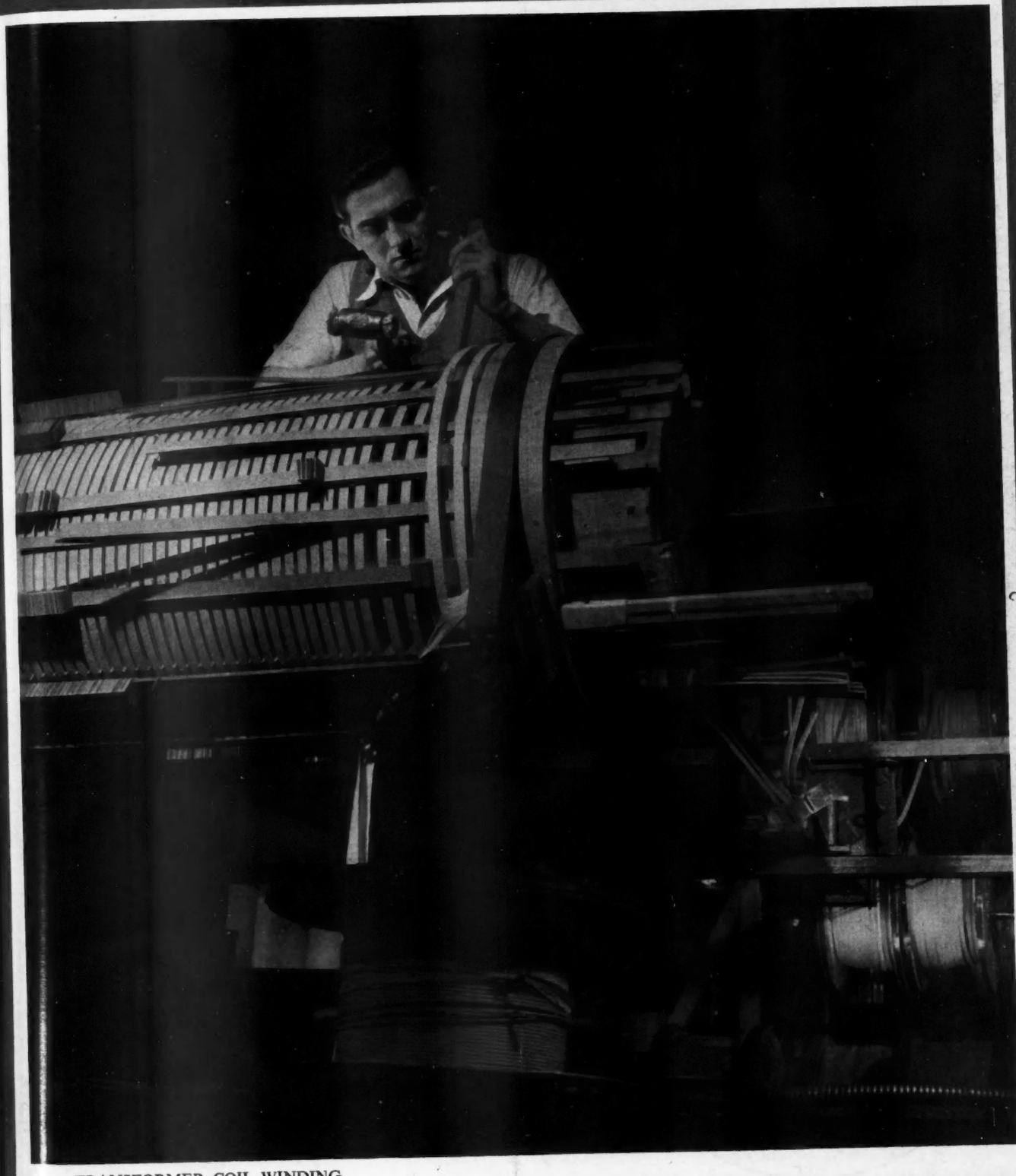

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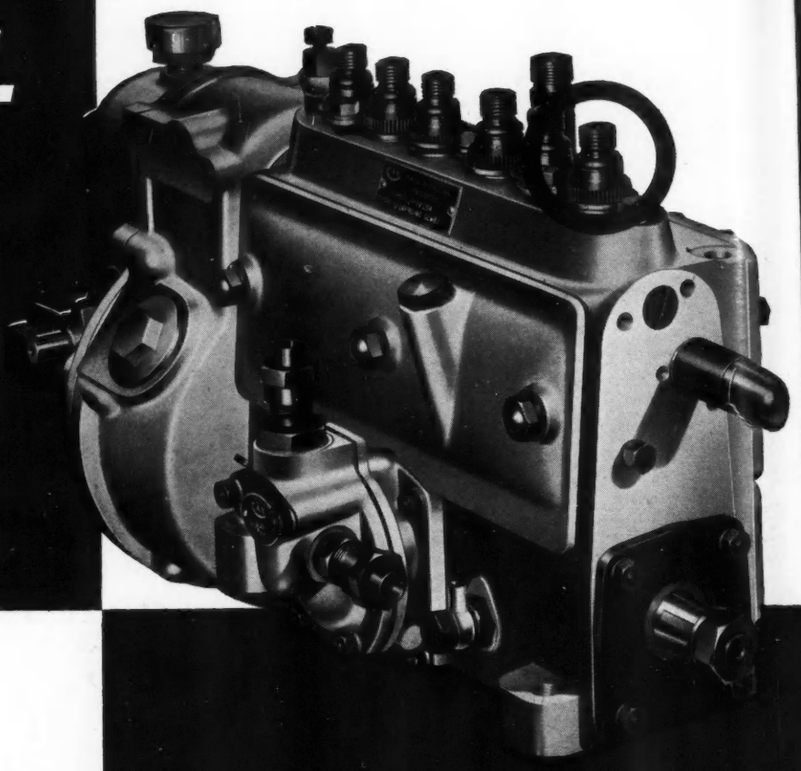

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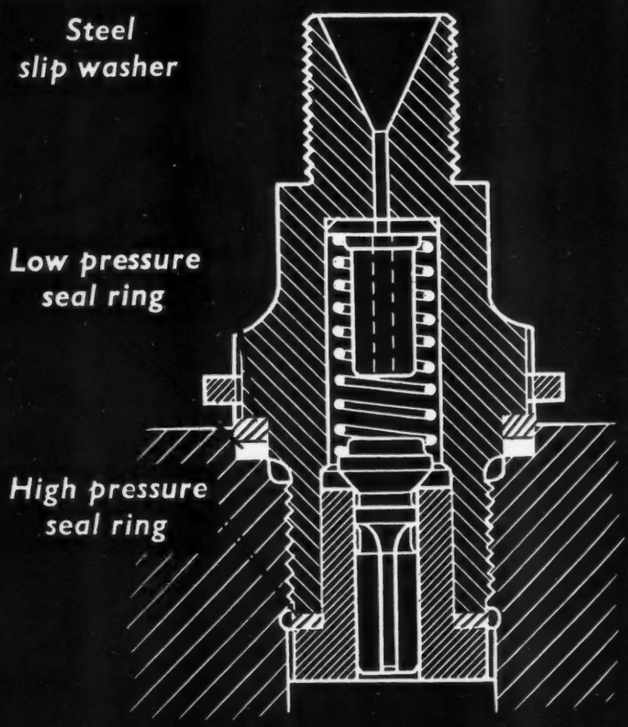

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WELDED SHIPS

THE annual report of Lloyd's Register of Shipping for 1954 contains some important statements regarding ship construction which, if not related properly to post-war developments, may give rise to misunderstandings. The sudden failure of ships at sea, welded construction, the phenomenon of brittle fracture—these and other factors are significant at the present time.

The fitness of ships to be classed at Lloyd's is based on the very comprehensive Construction Rules. The Committee of Lloyd's Register are responsible for controlling the application of Lloyd's Rules to class assignment and maintenance. During the war and since, a number of problems have arisen. By far the most difficult of these has been the extent to which structural modifications should be called for in ships built and classed in the period of transition between riveted and welded construction. This fundamental change was accelerated by the war in the overriding interests of economy in time, materials and labour. Before the second World War, welding in British ship construction had been limited to parts other than strength members, and had it not been for the war the extension of its use would have been slower and would have proceeded in the light of experience gained in service. This policy of permitting fundamental change only as it was proved in service was adopted by the Society in other far-reaching changes, such as from wood to iron, and from iron to steel. When these changes were made the Committee insisted on a waiting period of ten years before changes in the construction rules were formulated to incorporate the experience gained in service. In the change from riveted to welded construction no such waiting period was possible, and investigation has since shown that an increase in the margin of safety is desirable in some ships built during that time.

Amendments to the Construction Rules have been made, as reported on page 328 of this issue. It has never been Lloyds' policy to make such amendments retrospective, and there were therefore a number of ships which could still be classed 100 A1 even though they might not fulfil all the up-to-date requirements. In order to assess the overall position, Lloyd's Register made a survey of 2,700 ships which might have been affected, and recommended structural modification in 280 cases. Many of these were Liberty ships, and most of them were of welded construction. The design of the Liberty ships, built in the United States during the second World War, stemmed from a British design, and they could be classed at the time they were built as 100 A1. The work of modification has naturally caused inconvenience to owners, and considerable financial outlay, but due to the good relations between Lloyd's Register and the shipping community the work has proceeded smoothly. The 280 ships have been modified as and when they have arrived in Britain and it has been possible to work on them. More than 90 per cent. of the 280 ships have been modified, and the whole work should be finished soon. Lloyd's report for 1954 says, in a paragraph on ship classification: "Every shipowner has a right to regard continuance of his ship in the Society's class as an indication that the Committee are fully satisfied with her efficiency to carry cargoes safely, even under adverse weather conditions, and in practically every case owners have accepted the structural modifications suggested by the committee."

The precautions necessary in these 280 ships were designed to reduce susceptibility to severe brittle fracture, and thus save them from failures that had already afflicted other welded ships. This phenomenon is not confined to welded ships. It has occurred in riveted structures, including bridges, but welded ships seem to be prone to it. In an article published in this journal in 1953, a member of the staff of Lloyd's Register, Mr. G. Murray Boyd, reviewed present knowledge of the propagation of fractures in mild-steel plates, and gave his interpretation of some of the characteristics of these catastrophic failures. They are characterised by "their suddenness, extensiveness, high rate of propagation, and almost complete absence of reduction in thickness at the fractured edges." Where it has been possible to trace the origins they have been found at notches, such as structural discontinuities, incipient cracks, or defects in welds. The fractures are not always confined to welds but often run off into the plating, and they are more common at low temperatures. A vast amount of research has been done but there is, so far, no simple or wholly satisfying explanation. But the risk of brittle fracture is being reduced by incorporating "crack arresters," which are artificial discontinuities in the structure of the ship. Almost all of the 280 cases of structural modification have been treated in this way. In the absence of precise theoretical understanding, Lloyds are thus able to continue their beneficent influence on ship construction.

The amendments to the Construction Rules will remove many of the sources of trouble and should result in a higher standard of security, but the pressing problem is evidently that of determining a reliable criterion for notch-toughness of steel. The efforts which are being made to that end are considerable, and it is to be hoped that a satisfactory solution will soon be reached.

Weekly Survey

Cover Picture: *The static transformer is a practical realisation of the principle of mutual induction. It is of simple construction, consisting of a laminated iron core over which two or more separate windings are laid. It has many specialist applications for measurement, welding, furnaces, X-rays, and in communications. It is a vital link in every system of alternating-current power transmission and distribution. The illustration shows the low-tension winding of a 9-MVA 132/10·8-kV transformer such as would form part of a primary distribution power network. It is made of insulated copper strip, which is formed into a number of discs so as to leave ducts between them for the cooling oil. Although the coil is mounted on a mandrel to facilitate handling, its assembly is a manual task in which skill and accuracy are essential.*

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MACHINERY FOR COMPETITORS

In the midst of the current controversy between the Lancashire cotton industry and the Government over the duty-free admission into this country of Indian grey cloth, voices have been raised against what appears to be the official policy of encouraging machinery exports at the expense of cotton goods. Mr. Percy C. Fish, chairman of J. F. & H. Roberts, Limited, is quoted in the Engineering Outlook article on textile machinery in this issue as saying: " The powers-that-be seem to have the idea that in order to get orders for capital goods such as textile machinery, etc., it is necessary to open wide the door into our home trade and Dominion markets for consumer goods such as manufactured textiles on ridiculously advantageous terms."

This is an old argument, often heard between the wars and particularly during the 1930's, when feeling against the " traitor exports " ran high. Essentially it is an expression of emotion rather than a reasoned statement. The industrialisation of countries such as Japan at the beginning of the century, and of India during the past 20 years, could not have been arrested except by the deliberate policy of the governments of industrialised countries through an all-embracing agreement to ban machinery exports, as has been done since the war in the case of Russia, China and other Communist countries. Nor would this be to the advantage of major exporters, since without exception an increase in total imports has accompanied the growth of industry in primary producing countries. As Mr. A. R. W. Low, also quoted in the article, points out: " The exports of capital goods make for the wealth which tomorrow will buy high quality consumer goods." It is, therefore, a question of change rather than slow death which faces Lancashire cotton—a change to finer cloths and high-quality goods which embody more of the traditional skills of the industry's workers.

The textile machinery industry is itself feeling the full weight of foreign competition, particularly German and Japanese. Like the cotton industry, it has a number of basic adjustments to make to withstand competition from local manufacturers in its largest markets, and these will inevitably involve a great deal of research and development work to keep ahead of the field with high-quality up-to-date machines, particularly machines to process artificial fibres. The industry is a very large one. Exports of textile machinery were, in fact, nearly twice as large as those of machine tools.

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AUTOMATION AND THE TRADE UNIONS

The reported meeting of shop stewards in motor-car factories to discuss the effects of automation lends interest to a series of articles that appeared recently in *C.I.O. News*, the journal of the American Congress of Industrial Organisations. American trade unions in the mass-production industries have a reputation for willingly accepting technological change and their anxiety over the introduction of electronic, automatic, self-controlling machines is therefore significant. In the words of Mr. Walter Reuther, President of the C.I.O., the second industrial revolution, like its Eighteenth Century predecessor, will effect great improvements, but it can also produce heavy casualties. Collective bargaining will not solve all the problems it creates; study and practical measures by government will also be required.

The trade unions' fears are that a new philosophy of design and manufacturing method is being developed without consideration of the vast social and human effects which it will bring in its train. Typical of this conflict is the reported question asked by a Ford Motor Company official of Mr. Reuther, to whom he was showing the automatically-controlled machines at the Cleveland plant: " How are you going to collect union dues from these guys?" To which Reuther replied: " How are you going to get them to buy Fords? "

Among the problems discussed in these articles is that of fitting the displaced production worker into the higher grade jobs that will become available. Professor Gordon Brown, of M.I.T., told the United Steelworkers Convention that this issue may become of importance " comparable with that of higher wages in a job classification that soon may not exist." Management might help by on-the-job training, well in advance of the introduction of an automatic process; labour must ensure that it is continuously informed on technical advances, is represented on technical societies and must face up to the reality of job-upgrading. Even existing high levels of skill may be inadequate.

Examples given of the changes brought about in a variety of industries by the spread of automation include oil refining, in which a 22 per cent. rise in production since 1948 has been accompanied by a reduction in number of workers from 147,000 to 137,000. The number of telephones per employee in the telephone industry has nearly doubled in a little over thirty years. The United Automobile Workers, in an industry where automation is rapidly advancing, have set up a special committee to study the new technological developments.

Apart from the fear of unemployment, which might be particularly serious in towns such as Detroit, where there is a high concentration of a single industry, the unions are mainly concerned to get the benefits of the machines in higher living standards and shorter working hours. Provided that they are satisfied that this will happen, they do not intend, even if they could, to stop the new machines.

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HEAVY MOTOR VEHICLES

Demand for heavy commercial vehicles in the past few years has grown considerably, and Leyland Motors Limited have been among the manufacturers who have benefited. According to the recent statement of the chairman, Mr. C. Basil Nixon, home sales improved steadily as the year progressed and, before its close, demand was so great that " special and urgent measures " had to be taken to speed up production. Export sales, which accounted for half the output, are claimed to have been a record in Leyland's line of business. The company have been particularly fortunate in that, despite a general fall in demand, they have obtained a good volume of orders for public-service vehicles. Total British output of these had fallen from 945 a month in 1950 to 597 in 1953. There was, however, some improvement to 673 in 1954, and Leyland received a high proportion of all orders placed by municipal authorities.

Four of the leading British bus undertakings, who have already purchased 1,500 Leyland buses since the war, have recently placed orders valued at £500,000. Much of this success is attributed to the excellence of the Leyland " 600 " engine—for which mileages of over 300,000 between major overhauls have been reported by customers. This engine is by no means confined to its use in buses: a 10-litre engine, it has a widening range of application throughout the whole field of medium-heavy transport (which includes the heaviest lorries in use in this country) as well as industrial uses—earth-moving equipment, compressors, generating sets, etc. On the Continent, where four-axle articulated lorries may have a gross vehicle weight of 35 tonnes, compared with 22·4 tons here, there is a trend to larger engines of up to 15-litre capacity. In the U.K., a 15·9-litre engine (the " 970 " of Henry Meadows, Limited) is used on a tractor but, so far, there is no application on heavy commercial vehicles. Nevertheless, other manufacturers including Leyland are understood to be developing engines of that size. Leyland no doubt are primarily interested in the application of the 15-litre in railcars, for which the market is growing rapidly, but there is also scope for installing it in heavy road vehicles for export. This development is in line with the company's policy, expressed by the chairman, " of taking every feasible step to hold leadership in design and production of heavy commercial vehicles." The fact that nothing is said about gas turbines, mixed-cycle units or air-cooled Diesel engines, suggests that the British heavy-vehicle industry has dismissed these ideas as commercial propositions. In this, they are at variance with some Continental and American opinions, but they may well be right.

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DORMAN LONG'S CAPACITY

Dorman, Long and Company, Limited, are responsible for about one-tenth of this country's output of steel ingots. Their size and their wide variety of interests, which include structural engineering and bridge building as well as iron and steel production, make them a typical example of the recent and prospective experience of the steel industry. The tremendous strides which the steel industry has made in the last eight or nine years in both output and productivity (it is sometimes overlooked that the steel industry increased its productivity between 1946 and 1954 by over 30 per cent.) are typified in the activities of this North-East Coast giant.

Steel-ingot production by Dorman Long has increased by about 45 per cent. since 1946, according to the annual review of Sir Ellis Hunter, chairman of the company. When the present development programmes at Lackenby and at the Cleveland works are completed the company expects to have added another 400,000 to 500,000 tons of ingot steel capacity to the group, and this third stage of the company's post-war development is expected to be achieved with the addition of only 500 employees. As is generally known, the work at Lackenby and Cleveland is well forward. Fabrication of the universal beam mill equipment for Lackenby, part of which is to be made in the United States, has already begun. American supply of plant represents about 20 per cent. of the expenditure on plant and equipment and about 12 per cent. of the total cost of the complete universal-beam and heavy-section mill installation. In this mill a combination of American and of British methods of rolling heavy sections are being employed and both carried to a further stage of development. Universal beams will be the main new product when stage 3 of the development plan is completed, but narrow strip will also be produced.

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THE DAVID BROWN CORPORATION

The products of the David Brown Corporation Ltd., covering gear units, industrial and agricultural tractors and agricultural implements, machine tools and luxury private cars, are a cross-section of an important part of the engineering industry. The annual report of the Corporation for the year ended June 30, 1954, indicates that the turnover of all branches is now over £15 million. An interesting table

accompanying the report shows that of the total turnover 61·74 per cent. went on materials, supplies, charges for services and other expenses, 27·5 per cent. on payments to and on behalf of all employees, and 10·76 per cent. represented profit, of which taxation took 4·32 per cent., profits retained in the business 4·12 per cent., depreciation 1·78 per cent., and dividends to shareholders 0·54 per cent.

In his review of the year the chairman stated that the improved results were achieved in spite of the fact that for ten months of the year conditions were unsettled owing to the prolonged negotiations regarding wage increases. There was strong pressure on component suppliers not only to absorb the increase in wages through greater productivity but even to reduce the price of components so that the end product would be more competitive in export markets. This year the wage negotiations have been completed more quickly, thus removing the disturbed conditions which must result from prolonged negotiations, but it must be a matter of some anxiety as to how far the recent increases, which on the average probably amount to about 5 per cent., can be absorbed without raising prices. It is interesting to note that on the figures given above an all-round increase of 5 per cent. in payments to employees would appear to be equivalent to about 1·35 per cent. of turnover or nearly three times the proportion paid in dividends to shareholders.

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WAGON SIZES

The British iron and steel industry relies to a very large extent on rail traffic for the carriage of its raw materials, fuel and products, and since the total quantity amounts to some 75 million tons per year, the industry has a vital interest in ensuring that they are delivered in the most suitable types of wagon. We print in this issue a report of an investigation made by the British Iron and Steel Research Association into the best types of wagon for bulk-material traffic. It is not possible to make direct use of experience gained in other countries because, having been pioneers in railway development, Britain has many lines on which there are severe restrictions of both width and height. Under these conditions, the large and heavy bogie wagons used on the Continent and in America would generally give trains of less carrying capacity than the lighter two-axle wagons which have been developed in this country.

The latest types of wagon are very efficient carriers, and the modified versions of them, which will no doubt be designed as the new British Railways' policies of upgrading track to take a 22½-ton axle load and of fitting continuous brakes come into effect, will compare very favourably with the bogie wagons used elsewhere. It will be essential for works to think ahead in their planning so that they can make full use of these new wagons. Some steelworks can already weigh and discharge wagons with a gross weight of 45 tons and most can accept the new 24½-ton coal wagon with 12-ft. wheelbase. At many collieries, however, the loading arrangements will need modification to take the new wagons.

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LONG-RANGE JET AIR-LINERS

The announcement during the past week that the Boeing Airplane Company have been awarded a new contract amounting to $460 million for their long-range jet aircraft, the KC-135, for the U.S. Air Force has considerable significance for the British aircraft industry in that it places the Boeing Company in a strong position in the development of long-range jet civil air-liners. The contract is the result of a design competition instituted by the Air Force for a jet tanker-transport and brings the total Air Force orders for the KC-135 up to $700 million (£250 million). The Lockheed Aircraft Corporation have also received a " phase one " contract for the design and development of an advanced jet tanker.

These three companies, particularly Boeing, are therefore well placed to compete with the later versions of the Comet and the civil version of the V.1,000 for the large long-range civil aircraft market which is expected to develop over the next few years. The speed with which these civil jet air-liners can be successfully developed may also have an important influence on the sales of the long-range version of the turbo-prop Britannia. The Boeing KC-135 is the military version of the 707 jet transport, originally developed by the Boeing Company as a private venture at a cost of $15 million. It is not yet known whether the company will be able to divert part of its current output for adaptation to civil use, but in any case the fact that they will be able to set off the very heavy development expenditure against the Air Force contract is a powerful advantage. One of the first U.S. airlines to place an order for jet aircraft will probably be United Airlines, who are reported to be considering the placing of an order valued at $50 million.

At this stage it would be impossible to forecast the probable result of the competition between British and U.S. manufacturers for the long-range civil air-liner market, since the Comet experience has shown how easily supremacy may be lost (even if only temporarily). Apart from the hazards associated with the development of new designs there remains the question of production costs and in this British manufacturers are believed at present to have a substantial advantage.

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LIGHTWEIGHT FIGHTER

The Folland Midge aircraft, the forerunner of the lightweight Gnat fighter which is expected to fly this summer, has completed 65 hours' test and demonstration flying, and is now being fitted with a wing similar to that of the Gnat—the principal difference between the original Midge wing and that of the Gnat being in the ailerons. The Midge had conventional manually operated ailerons at the outboard ends of the wings, whereas those of the Gnat will be located inboard and will be power-operated over a large range of angular movement, which, it is believed, will give the aircraft an exceptionally high rate of roll—200 deg. a second or more is predicted—without imposing undue twisting forces on the wing.

The Gnat and its forerunner are designed by Mr. W. E. W. Petter, managing director of Folland Aircraft, Limited, Hamble, and up to the present it has been developed as a private venture. It is the contention of Mr. Petter—and many will concur with him—that owing to the high cost in man-hours and materials of producing and maintaining in serviceable condition the highly complex high-speed fighter aircraft of the type now coming into service, such machines will be severely limited in number and in possible applications, and that there is a real need for a simpler, less expensively equipped lightweight fighter that can be operated away from base. The Gnat is Mr. Petter's approach to this problem, and the Midge is an interim version designed to give flying experience pending the arrival of the Bristol Orpheus engine, now on bench trials, which is to power the Gnat. The Midge is fitted with an Armstrong Siddeley Viper engine developing 1,640 lb. thrust—about one-third of the thrust expected from the Orpheus.

Flying trials on the Midge have gone well. The Viper engine has played a considerable part in the success of these trials, having proved itself to be highly reliable. Although underpowered, the Midge has been dived to supersonic speed with, it is stated, only a slight change of trim as sonic speed was approached, and with no buffeting.

The Midge starts to stall at about 105 knots, but the stall is not fully developed until the control column is right back, and there is no tendency to instability at any stage of the stall. Lateral, directional and longitudinal stability characteristics are said to be good. More work has yet to be done in analysing trim changes at high speed but experience has shown that such changes as do occur can be held single-handed. Without using a braking parachute, the landing run is about 750 to 1,000 yards. With the braking parachute and standard brakes, landing runs as short as 450 yards have been achieved in still air. More work has still to be done to determine the best landing technique.

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EAST MEETS WEST

The large number of Western exhibitors at the Leipzig Fair is a measure of the extent of the growing interest in the possibilities of East-West trade. Over 70 British companies were represented, including manufacturers of engineering products, such as agricultural tractors, earth-moving machinery, pumps and Diesel engines. A number of useful orders were booked, but not all the exhibitors appear to be convinced that it will be worth exhibiting next year. Inquiries were numerous, but exhibitors complained that many were made by official bureaucratic buyers who could give little technical information about the type or quality of product required.

The prospects for increased engineering exports to China are also somewhat better, although recent negotiations with the China National Import and Export Corporation have not resulted in large orders for engineering products. The group of 24 British business men who arrived in Peking on February 5, after 12 days negotiation signed 130 contracts valued at £4 million. Business in engineering products was, however, insignificant on this occasion due, at least partly, to the reluctance of the Chinese to enter into contracts for commodities for which, owing to the embargo, delivery could not be guaranteed. Nevertheless, there was strong evidence of a desire to do business with British business men. The British group affirm that there are expanding trade possibilities, particularly for engineering goods, and do not consider the Chinese estimate " unrealistic." The subject is, of course, fraught with a tangle of political uncertainties, but the group can, at least, fairly claim to have laid some sound foundations for future trade.

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WORDS AND PICTURES

There is to-day a slight undercurrent of dissatisfaction with the conventional methods of presenting scientific and technical information. The text in ordinary narrative form, punctuated by references to accompanying illustrations, is regarded as unsuited to the utilitarian task of conveying information.

An article in this issue is a case in point. It discusses the requirements for railway wagons designed to carry iron ore, etc. The information consists almost wholly of a series of relationships between, for example, number of axles per wagon and load per unit length of train. This information could have been presented as a series of simple graphs with a running commentary, and perhaps two normal-style paragraphs—one to introduce the article and the other to give any recommendations or comments that could not be shown graphically.

In a letter published in this issue, Mr. R. T. Carr states his belief that the graphic form of presentation could be used for all kinds of information. He over-states the case. But the idea remains: a revolution in the presentation of technical information. Like all revolutions it would reveal for the first time some virtues of the old system. It would probably confirm a suspicion that continuous text has its own attractions, a result of the nature of men and women and literature, which compel the casual as well as the serious reader to taste before rejecting. And if the words are deployed skilfully they will hold the attention of everyone for whom they have a message—and bore those for whom they are irrelevant. That is the ideal, but it is seldom reached. Perhaps pictures could sometimes do more good than words.

SHIP DESIGN AND CONSTRUCTION

THE INFLUENCE OF LLOYD'S REGISTER

The annual report of Lloyd's Register of Shipping for 1954 concentrates on the work that the Society is doing to ensure proper standards of safety in ships. Experience with post-war construction methods and the higher speeds now customary led the Society to set up a special panel to consider what amendments to the construction rules were necessary to ensure a satisfactory standard of longitudinal strength in certain types of design and construction. The amendments suggested by the panel were adopted by the General Committee on December 9, 1954, and were briefly described in ENGINEERING of December 17, 1954, page 782.

The first question dealt with by the new amendments is the effect of present-day design arrangements and increased speeds on longitudinal scantlings. Modern dry cargo ships, with much finer form, longer machinery space amidships and cargo disposed more towards the ends, are generally subject to much greater hogging stress than older type ships. There is also the effect of higher speeds, particularly in bad weather. Consequently, in order to ensure a satisfactory standard of longitudinal strength and to cover all types, it has become necessary to introduce into the Rules formulae whereby the minimum scantlings based on dimensions will be increased when necessary to take account of modern design characteristics, in respect of cargo space distribution and speed. This requirement will apply irrespective of the mode of construction, that is, whether the ship is welded or riveted.

The optimum longitudinal distribution of cargo and fuel load in the modern cargo ship necessary to minimise longitudinal stress is a factor requiring the careful attention of designers. The greater structural efficiency derived from longitudinal framing is now generally recognised, and the majority of new cargo ships are being designed with longitudinal framing at both bottom and deck.

The second main question dealt with in the recent Rule amendments concerns welded construction. Although much progress towards a higher standard of structural efficiency is being made, experience continues to emphasise the absolute necessity, in welded construction, for care in structural design and workmanship in order to eliminate, so far as possible, all sources of fracture initiation. In all-welded ships prevention of serious propagation of a fracture, if initiated, must finally depend upon the toughness of the steel.

Concurrently with the work on the Rule amendments a comprehensive investigation was undertaken into those existing classed dry cargo ships which, in the light of recent experience, might be deemed subject to the risk of failure under adverse weather conditions. Over 2,700 cases were examined, and the Committee considered it necessary to recommend some structural modification in about 280 ships. This work has been nearly completed.

NOTCH-TOUGH STEELS

Experience with welded structures has emphasised the necessity of providing steel having the requisite notch-toughness to resist rapid propagation of fracture, especially at low temperatures. As the result of research into early wartime failures, the Society's Rules were amended in 1950. A minimum manganese/carbon ratio of 2·5 was imposed for all steel over $\frac{1}{2}$ in. in thickness and, for plates over 1 in. used for structurally important parts of welded ships, the steel was required to be of a quality specially approved. From the limited service experience to date it appears that these specially approved steels have been effective. Recent cases, however, have indicated that for plating appreciably below 1 in. in thickness, the prescribed minimum manganese/carbon ratio of 2·5 may not provide sufficient safeguard against brittle fracture. The Rules have therefore been recently amended to extend the use of specially-approved steels to thicknesses of less than 1 in. for the main structure of welded ships.

The problem of providing structural steel of the requisite notch-toughness has proved to be extremely intricate. It has not yet been possible to discover simple production tests which can be confidently prescribed as a reliable criterion of service behaviour. Research into this problem continues in Britain and other countries, and the Admiralty Ship Welding Committee has recently been re-constituted as an Advisory Committee on Structural Steel. On this Committee steel users (both marine and non-marine), steelmakers, research institutions and Lloyd's Register are represented. The Society is also watching the results of the oxygen-blown basic converter process, a recent and important development in steel-making practice. This has followed several years of experimental work undertaken mainly in Europe, with the object of producing a type of steel which, although made in a basic lined converter, would be comparable in all its properties with Siemens Martin steel.

PROPELLING MACHINERY

Developments in all types of propelling machinery are proceeding steadily, with resulting economies in fuel and space. The recent reform of the tonnage regulations may well result in the introduction of new ideas in engine-room layout and propelling machinery. Heavy oil engine progress has been concerned with obtaining increased outputs by pressure charging and with the developments of medium and high speed engines of various types. Powers up to 6,000 brake horse-power per engine are now available with V-type 16-cylinder engines of advanced design. A new feature in small auxiliary engines is the use of air instead of water for cylinder cooling. Much attention has been given to the burning of residual fuels, and as a result of operating experience it is becoming the practice to isolate cylinders from the crankcase by a diaphragm plate and so minimise the possibility of corrosion of running parts and contamination of lubricating oil by combustion products. During the past year a preference for the two-stroke cycle heavy oil engine has continued; the single-acting type in particular represents some 80 per cent. of the total fitted for propelling purposes. A new German cargo liner, the Lichtenfels, has two geared M.A.N. highly supercharged four-stroke oil engines of the crosshead type. The turbo-supercharger consists of a 3-stage exhaust gas turbine driving a 14-stage axial compressor and supplies cooled air to the engine at a boost pressure of 35 lb. per sq in.

The direct-fired gas turbine intended for long-life merchant service has been the subject of continued research and development in Great Britain and elsewhere, but no real progress for main propulsion can be expected until operating experience with a sizeable unit under sea-going conditions is available. Apart from the small unit fitted in the Auris, there are no gas turbines in merchant ships. Free-piston gas generators in conjunction with geared exhaust gas turbines are now operating as main propulsion units in two French coasters and an installation incorporating three generators and a power turbine is being built to Class. Gas turbines of this type present few difficulties with materials as gas temperatures are no higher than in normal steam turbine practice.

RESEARCH

The Society's research staff have, as their first task, the investigation of general technical problems, but their services are freely at the disposal of shipowners, shipbuilders and engineers to assist them with their problems. The investigations carried out during 1954 embraced a wide variety of service breakdowns and defects in boilers, turbines, gearing, heavy oil engines, propellers, shafting, hull and local vibration, noise problems, etc. The new engineering laboratory at Crawley is now in operation, where a number of investigations have been made which previously had to be referred to other laboratories. The fatigue testing machines, including the large machine taking 10-in. diameter solid forged specimens, are fully engaged for many months ahead. The Society has also received a number of requests from manufacturers for the fatigue testing of 3-in. diameter specimens of various wrought and cast alloys employed in marine practice.

There are a number of tables in the Report, which show: age distribution of world fleets; age distribution of tanker fleets; world tonnage of oil tankers; flag distribution of world tonnage; new ships completed and classed by Lloyd's Register during 1954; propulsion analysis of world tonnage; fuel analysis of world tonnage. Tonnage now under the Society's supervision is 41,235,570 tons gross, a net increase in twelve months of 1,885,026 tons. The number of ships increased by 64 to 10,012.

* * *

MARINE ENGINEERS' ANNUAL DINNER

The expanding responsibility of the marine engineer and the continued dependence of the British Isles for food supplies on sea transport were two topics referred to in speeches at the annual dinner of the Institute of Marine Engineers. Chairman at the dinner, which took place on March 11, was Mr. H. A. J. Silley, President of the Institute, and among the principal guests were the Rt. Hon. The Lord Mayor of the City of London, Sir Harold Walter Seymour Howard, Kt.; the Belgian and Netherlands Ambassadors; The Rt. Hon. W. R. Milligan, Q.C., M.P., the Lord Advocate; and Mr. A. I. Anderson, President of the Chamber of Shipping.

In proposing the toast "The Right Honourable the Lord Mayor of the City of London and the Sheriffs," the chairman spoke of the Institute's new headquarter building, the contract for which commenced on last March 7. It would, he said, be the only headquarters of a technical institute in the City, and the Institute was indebted to the Corporation for its help. In reply the Lord Mayor stressed the maritime traditions of this country and the Elizabethan heritage of seamanship and discipline.

The toast "The Royal and Merchant Navies of the British Commonwealth," was proposed by His Excellency The Marquis du Parc-Locmaria, the Belgian Ambassador, and in his response Mr. Anderson said that no-one disputed the importance of air power, but without ships the people would starve and aircraft would be grounded.

He continued by saying that the two greatest advances in British marine history had occurred during the reigns of queens: the development of the first ocean-going sailing ships during the reign of Queen Elizabeth I; and the conquest of the sailing ship by the engineer in the time of Queen Victoria. Possibly a new phase, in which the boiler-room would be manned by nuclear physicists, would begin during the present reign.

The marine engineer was infiltrating into many parts of the ship. He was now, for example, responsible for the air the traveller breathed and, with the advent of the stabiliser, even the quantity he ate. He was also required to explain technical matters in plain language, for at sea higher mathematics and lower expletives became indistinguishable. In conclusion Mr. Anderson declared that we could not rely on providence for progress, and it was up to the marine engineer to show for a third time what he could do.

In replying to the toast "The Institute of Marine Engineers," proposed by the Lord Advocate, the chairman said that the Institute had now more than 8,500 members. He hoped that the new headquarters would be occupied in three years and acknowledged the help received from oil and shipping companies.

PERSONAL

To fill vacancies on the University Grants Committee, the Chancellor of the Exchequer has made four new appointments and has also appointed two additional members. The new members, whose appointments will expire on December 31, 1959, are PROFESSOR R. S. EDWARDS, B.Com., University of London ; DR. WILLIS JACKSON, F.R.S., Metropolitan-Vickers Electrical Co. Ltd.; PROFESSOR R. H. MATTHEW, C.B.E., M.A., University of Edinburgh; PROFESSOR P. B. MEDAWAR, F.R.S., University College, London; PROFESSOR A. ROBERTSON, F.R.S., University of Liverpool; and SIR GEORGE THOMSON, F.R.S., Master of Corpus Christi College, Cambridge.

SIR HAROLD ROXBEE COX, Ph.D., M.I.Mech.E., F.R.Ae.S., who was director, National Gas Turbine Establishment from 1946 to 1948 and chief scientist, Ministry of Fuel and Power from 1948 to 1954, has been appointed an independent member of the Council of the Air Registration Board in place of the late SIR MAURICE DENNY.

MR. S. J. W. GOOCH, C.B.E., M.I.C.E., chief civil engineer, Crown Agents for Overseas Governments and Administrations, is retiring on May 31. His successor will be MR. W. FAIRLEY, M.A. (Cantab.), M.I.C.E., who has been deputy chief civil engineer since 1949. The post of deputy chief civil engineer is to be filled by the promotion of MR. J. H. P. HAWTREY, B.Sc. (Eng.), A.C.G.I., A.M.I.C.E., who entered the service of the Crown Agents in 1948.

MR. A. R. NORTHOVER has resigned from the board of directors of Hoover (Washing Machines) Ltd., and has relinquished his appointment as general manager of the company. MR. W. J. T. DIMMOCK, A.M.I.Prod.E., has been appointed to succeed him as general manager.

MR. F. BATEMAN and MR. R. F. MARSHALL, B.Sc. (Eng.), A.M.I.Mech.E., have been appointed assistant managers, education department, Metropolitan-Vickers Electrical Co. Ltd., Trafford Park, Manchester, 17. MR. D. R. DAVIES, M.I.E.E., for many years chief metal-clad switchgear designer at Trafford Park, has been appointed consulting designer.

In connection with the election of MR. R. H. GUMMER, M.I.Mar.E., F.Inst.F., as the next President of the Institute of Fuel, announced on page 231 of our issue of February 25, we have been informed that the data provided to us were inaccurate in one respect. Mr. Gummer is a director of International Combustion (Holdings) Ltd., and not of International Combustion Ltd.

MR. A. H. MASON, A.M.I.Prod.E., has been appointed technical manager, B.S.A. Tools Ltd., Mackadown-lane, Kitts Green, Birmingham, 33. MR. V. R. WINROW, M.I.Prod.E., has been appointed chief draughtsman and MR. G. C. J. LEGG, A.M.I.Mech.E., M.I.Prod.E., deputy general manager, of the Cardiff division of the firm.

MR. G. S. BINGHAM, M.I.Mech.E., M.I.Loco.E., M.Inst.T., at present assistant mechanical engineer (running) has been appointed assistant mechanical engineer (works) in the department of the chief mechanical engineer (railways), London Transport Executive, 55 Broadway, S.W.1. MR. J. G. BRUCE, B.Sc. (Eng.), M.I.E.E., M.I.Loco.E., M.Inst.T., at present assistant mechanical engineer (works), has been appointed assistant mechanical engineer (running).

MR. P. A. ANDREW, the first President of the Institute of Packaging, has joined the board of United Marine (1939) Ltd., packers of machinery, equipment and instruments, 64 Queen-street, London, E.C.4.

WILSON AND RODGER, consulting engineers and designers, Western-avenue, Ealing, London, W.5, have changed their name to RODGER, SETTERINGTON AND PARTNERS, consequent upon the retirement of MR. A. C. WILSON from the firm. MR. D. W. SETTERINGTON, B.Sc. (Eng.), D.L.C., A.M.I.C.E., A.M.I.Struct.E., has been a partner in the firm for the past eight years. The address and policy of the firm remain unchanged.

MR. L. JAGO, A.M.I.Mar.E., at present technical representative in the London area of Fodens Ltd., Elworth Works, Sandbach, Cheshire, has succeeded MR. R. G. VACY-ASH as manager of the Marine Division of the firm. Mr. Vacy-Ash has retired after 22 years of service with the company.

MR. R. A. KIRBY, A.I.R.I., has relinquished his position as works manager of the rubber and plastics cable factories of Enfield Cables Ltd., Victoria House, Southampton-row, London, W.C.1, in order to take up an appointment with the firm's subsidiary company, Enfield Cables (Australia) Pty. Ltd. MR. H. E. TICKNER, A.M.I.Prod.E., formerly in charge of the paper-cable factory only, has now been appointed works manager—cables, in charge of all three cable-making works. The company's subsidiary cotton covering factory at Blaenavon, Wales, has been closed down and this production transferred to the main works at Brimsdown. MR. W. G. TURNER, who was in charge of the Blaenavon factory, has been made manager, covered-wires department, Brimsdown.

MR. R. H. STEEDS has been appointed regional manager (Scotland) of British Insulated Callender's Cables Ltd. He will work from the firm's Glasgow office.

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COMMERCIAL

At the beginning of April the sales division of the AEROGRAPH CO. LTD. will move into new offices at 47 Holborn-viaduct, London, E.C.1. The factory and head office remain at Lower Sydenham, London, S.E.26.

DOWTY GROUP LTD., Cheltenham, have purchased the Cheltenham firm of DAVIS, WYNN AND ANDREWS, manufacturers of instruments used in electronics. MR. G. H. DOWTY, F.R.Ae.S., is to be chairman of the new company and MR. T. D. H. ANDREWS, managing director, is being retained as technical director.

GUY MOTORS, LTD., Wolverhampton, have launched a new company, GUY MOTORS SOUTH AFRICA (PTY.) LTD., which will have depots in Cape Town, Johannesburg, Durban and Salisbury, Rhodesia.

A new company, ADASTRA HUNTING GEOPHYSICS LTD., has been formed by ADASTRA AIRWAYS PTY. LTD., Mascot, New South Wales, Australia, and HUNTING GEOPHYSICS LTD., 4 Albemarle-street, London, W.1, to carry out air-borne geophysical surveys in Australia.

* * *

CONTRACTS

Heavy-Water Plant. An order by Geothermal Development Ltd., for a heavy-water plant to be erected in the Wairakei district of North Island, New Zealand, has been placed with HEAD WRIGHTSON PROCESSES LTD., Teesdale House, 24–26, Baltic-street, London, E.C.1. The plant includes a power station, a compound unit and a water-pumping station. Energy for the operation of the plant is obtained from steam taken from hot springs at Wairakei, and the separation of the heavy water is achieved essentially by distillation. The steam is also used in turbo-alternators to generate electric power.

Power-Station, Transforming-Station and Transmission-Line Equipment. Contracts were placed by the British Electricity Authority during February for power-station, transforming-station and transmission-line equipment, amounting in the aggregate to £10,536,075. The principal contracts include: for Belvedere power station, Erith: two 60,000-kW turbo-generators, with the ENGLISH ELECTRIC CO. LTD. For Littlebrook "C" power station, Dartford: high-pressure pipework and valves, with C. A. PARSONS & CO. LTD. For Marchwood power station, near Southampton: one 60,000-kW turbo-generator, with the ENGLISH ELECTRIC CO. LTD. For Portishead "B" power station, near Bristol: one 60,000-kW turbo-generator, with the METROPOLITAN-VICKERS ELECTRICAL CO. LTD., and high-pressure pipework and valves, with STEWARTS AND LLOYDS LTD. For Tilbury power station: 11-kV and lower-voltage cables and accessories, with MALCOLM AND ALLAN (LONDON) LTD. For Willington "A" power station, near Derby: 3·3-kV auxiliary switchgear, with the ENGLISH ELECTRIC CO. LTD. For Rogerstone power station, Monmouthshire: piling for main foundations, with A. WADDINGTON & SON, LTD. For Ince power station, near Ellesmere Port: four 550,000-lb. per hour boilers, with INTERNATIONAL COMBUSTION LTD. For Elland power station, Yorkshire: one 60,000-kW turbo-generator, with the METROPOLITAN-VICKERS ELECTRICAL CO. LTD. For Ferrybridge "B" power station, Yorkshire: 415-volt auxiliary switchgear, with BROOKHIRST SWITCHGEAR LTD. For Chadderton power station, Oldham: high and low-pressure pipework, with STEWARTS AND LLOYDS LTD. For Dalmarnock power station, Glasgow: a reinforced-concrete chimney and supporting structure, with TILEMAN & CO. LTD. For North Hammersmith substation: two 15-MVA 66/11-kV transformers, with FERRANTI LTD. For Herrington Burn substation: two 75-MVA 132/66-kV main transformers and one auxiliary transformer, with FERRANTI LTD. For Manchester Grid control area a standardised system of general indication and telephone equipment, with AUTOMATIC TELEPHONE AND ELECTRIC CO. LTD.

Power-Station Lubrication. The latest major contract received by MARINE AND INDUSTRIAL LUBRICANTS, LTD., is for the supply of their Morola 45-I.T. inhibited turbine oil to the new Hackney "B" power station. The contract also includes the lubrication of machinery in the boiler-plant section and all station-plant auxiliaries.

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Obituary

MR. C. M. MAYSON

We regret to record the death of Mr. C. M. Mayson, which occurred at St. Albans on Tuesday, March 1, in his 83rd year. He had for long been connected with the supply of electricity in London; and had played a leading part in re-organising and modernising the mains system in the West-Central area.

Christopher Mark Mayson was born at Cockermouth, Cumberland, on May 4, 1872, and was educated at St. Bees School. He served a year's apprenticeship in the locomotive works of the Caledonian Railway in Glasgow; and in 1891 attended the Central Technical College, London, where he gained a first-class in the final examination. In 1895 he became an improver in the electricity works of the Whitehaven Corporation and a year later was appointed engineer-in-charge.

His connection with London's electricity supply began in 1899, when he obtained the newly created position of substation engineer in the West End area of the Charing Cross, West End and City Electricity Supply Company, under Mr. W. H. Patchell. During the 1914-18 war he was additionally appointed deputy chief engineer under Mr. W. B. Thorpe, and between them they undertook the task of re-organising and modernising the electricity distribution arrangements.

This work included the re-placement of the existing Diesel-engine generators by others of a more modern type to provide an alternative direct-current supply to theatres and public buildings, as required by the London County Council regulations. He was also responsible for modernising the rotary converter and motor-generator plant and for installing automatic substations under Soho-square and in Aldwych House. His other activities included the laying of an alternating current ring-main system with transformers on the premises of large consumers. He retired in 1937 when the Charing Cross Company was absorbed by Central London Electricity.

Mr. Mayson was elected an associate of the Institution of Electrical Engineers in 1896, transferred to the class of associate member in 1899 and became a member in 1920. He was a past-president of the Diesel Engine Users Association.

* * *

ENG. CAPT. EDGAR C. SMITH, O.B.E., R.N. (ret.)

It is with deep regret that we record the death of Engineer Captain Edgar Charles Smith, O.B.E., R.N. (ret.), which occured at his home, Dalcouth, Keeper's Corner, Burstow, near Horley, Surrey, on March 13. He was in his 83rd year and had been a valued contributor to our columns for more than 50 years. We shall publish a memoir of Captain Smith in our issue of next week.

* * *

We regret also to record the deaths of:

MR. GEOFFREY TEMPLE PERKINS, in a road accident on February 28, at the age of 45. Mr. Perkins had held the post of technical sales manager of Smiths Aircraft Instruments Ltd., since 1948.

MR. LEWIS RAYMOND LANGMEAD, who was killed with Mr. Perkins in the same road accident, was 38 years of age. He had been technical service manager of Smiths Aircraft Instruments Ltd., for less than a year.

Letters to the Editor

APPROXIMATION FOR THE POLAR INVOLUTE FUNCTION

SIR, The articles on the approximation to sec θ which appeared in ENGINEERING* interested the writer as a derivation had been given previously by him in his book† published in 1951. This approximation suggested that the polar involute function used in gear calculations might be treated in a similar way. Many approximations for transcendental functions are good over a small range of variable, but it is unusual to obtain one so close over such a large range as that due to H. A. Webb.

The method of attack on the involute function which proved successful was to use the initial terms of the infinite series as an approximation for the function for small values of the variable, and then modify the expression to suit the form at large values. This procedure is somewhat reminiscent of the justification of Rankine's empirical formula for struts. The polar involute function may be defined in the following way. Referring to the diagram, the polar co-ordinates R, ϕ of the point P on the involute springing from the base circle at Q in terms of the parameter θ are:

$$\phi = \tan\theta - \theta \quad . \quad . \quad (1)$$

$$R = r \sec\theta. \quad . \quad . \quad (2)$$

Thus ϕ is a function of $\frac{R}{r}$, and is usually written $\phi = \text{Inv}\,\frac{R}{r}$. Since ϕ and $R - r$ tend to zero at the same time, it is convenient to change the variable to $\frac{(R-r)}{r} = \rho$, so that

$$\rho = \sec\theta - 1. \quad . \quad . \quad (3)$$

The infinite series for tan θ and sec θ begin as follows:

$$\tan\theta = \theta + \tfrac{1}{3}\theta^3 + \ldots \quad . \quad (4)$$

$$\sec\theta = 1 + \tfrac{1}{2}\theta^2 + \ldots \quad . \quad (5)$$

Thus for small values of θ,

$$\phi \simeq \tfrac{1}{3}\theta^3, \quad \text{and} \quad \rho \simeq \tfrac{1}{2}\theta^2.$$

Eliminating θ gives

$$\phi^2 \simeq \tfrac{8}{9}\rho^3 = \frac{\rho^3}{1 + \frac{1}{8}} \quad . \quad . \quad (6)$$

a good approximation for small values of ρ.

When θ approaches $\frac{\pi}{2}$, tan θ and sec θ (which are, of course, related by the equation $1 + \tan^2\theta = \sec^2\theta$) tend to the same infinity, and therefore to a 1/1 ratio. It follows therefore that ϕ and ρ must also tend to a 1/1 ratio when θ approaches $\frac{\pi}{2}$. The equation (6) may easily be modified to suit this requirement without impairing the approximation at low values of θ by replacing the unity in the denominator by $\rho + 1$. Thus the approximation becomes

$$\phi^2 \simeq \frac{\rho^3}{\rho + \frac{9}{8}}. \quad . \quad . \quad (7)$$

The equation in this form is remarkably close to the involute function as may be seen from the following calculations:

θ degrees	True value of ϕ	ϕ calculated from equation (7)	Fractional error
15	0·006 149 8	0·006 150 9	$1{\cdot}79 \times 10^{-4}$
30	0·053 751 2	0·053 787 7	$6{\cdot}74 \times 10^{-4}$
60	0·684 853 2	0·685 994 3	$16{\cdot}7 \times 10^{-4}$

In gear tooth profile calculations θ is rarely greater than about 30 deg., where the error involved in using the approximation is less than 7 parts in 10,000.

It might be expected from the success with the above function that a similar method could be used on the inverse function, namely ρ as a function of ϕ. The equation would then be $\rho^3 = \frac{9}{8}\phi^2(1 + k\phi)$ where, if $k = \frac{8}{9}$, the values of ϕ and ρ will agree at very small and very large values of ϕ. This is not the case however owing to the large variations in k required for intermediate values. Comparison with equation (7) also suggests that it cannot be suitable over a range of values.

The solution of equation (7) for a given value of ϕ yields a cubic equation with one real root, and an approximation to this root yields the equation

$$\rho = 1{\cdot}0400\,\phi^{\frac{2}{3}}(1 + 0{\cdot}3082\,\phi^{\frac{2}{3}}). \quad (8)$$

This equation is a remarkably close approximation as may be seen by the following table:

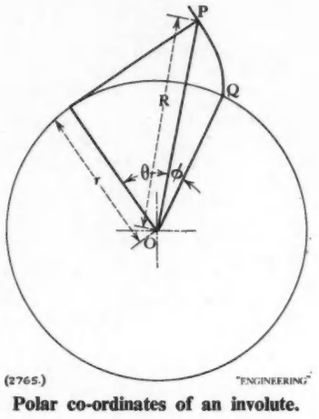
θ degrees	True value of ρ	ρ calculated from equation (8)	Fractional error
15	0·035 276	0·035 270	$-1{\cdot}6 \times 10^{-4}$
30	0·154 700	0·154 627	$-4{\cdot}8 \times 10^{-4}$
60	1·000 000	1·001 519	$15{\cdot}2 \times 10^{-4}$

Your faithfully,
J. JENNINGS.

6 Coronation-road,
Windle,
St. Helens, Lancs.
March 4, 1955.

* T. A. S. Jackson, L. Rosenhead and T. Murphy, "Webb's Approximation for Sec θ," vol. 176, page 298 (1953); and G. Pearson, "The Secant Approximation and the Perry Formula: Expressions for Eccentrically-Loaded Struts," vol. 178, page 594 (1954).

† *Mathematical Solution of Engineering Problems.* E. & F. N. Spon, Limited.



Polar co-ordinates of an involute.

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CONVEYING INFORMATION GRAPHICALLY

Scope for Improved Communication

SIR, Mr. Leslie Wilson did well to draw attention, by his letter in your issue of February 25, to "machinery for disseminating technical information." But even if the machinery be adequate for dissemination, in that it makes information available, it is inadequate in the form and presentation of the matter conveyed. Ability to communicate ideas has not kept pace with the tempo and complexity of our civilisation.

Published scientific and technical material deserves more skilful and painstaking preparation than research workers and technicians can give to it. Normal sub-editing tends to be hasty and discreet rather than inspired. Much of the cost of better preparation would be borne by reduction in printing costs, for a wholly competent writer requires only a fraction of an average paper's or text-book's length in which to communicate the essence of its content. Summaries and abstracts are incomplete and convey disjointed information.

Conventional continuous text is inadequate in principle for the presentation of complicated arguments. These commonly require semi-diagrammatic presentation analogous to that of a genealogical tree. Similarly, tabulation greatly simplifies and orders certain material. I believe that it is practicable to systematise the body of knowledge itself along semi-diagrammatic lines logically representative of the matter conveyed: "diagrams" employing a fraction of the words in the original sources of their information dovetail into diagrams representing closely-related subjects. A whole field of knowledge can be displayed at once in proper relationship, with cross-references to contiguous fields and to fundamental theories similarly grouped for display. For the proper, unrepetitive recording and filing of rapidly expanding knowledge, or for its organisation, a central authority is required.

I am, Sir,
Yours faithfully,
R. T. CARR.

Winnington Hall Club,
Northwich,
Cheshire.
March 9, 1955.

(*Editorial comment in Weekly Survey.*)

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TECHNICAL SERVICES OF PUBLIC LIBRARIES

West London System

SIR, Whilst I do not propose to enter into an argument with Mr. Wright on statistics regarding the respective size of technical stocks held by technical college libraries versus public libraries, I would like to mention that the Manchester technical and commercial libraries (public) carry 60,000 technical volumes, 5,000,000 patent specifications, 10,000 trade catalogues, 70 indexing and abstracting services, 800 directories, 750 technical and commercial journals, complete sets of British Standards, etc. Indeed, all our large industrial towns such as Liverpool, Glasgow, Leeds, Birmingham, Sheffield, Bristol, Newcastle-upon-Tyne, make similar provision according to their size and needs.

The ten public library systems of West London, which collectively cover an area similar to the operative area of the Manchester Public Libraries, are able to supply an equivalent service by co-operation. Any firm or person working in West London may, without formality, telephone, write to, or call at the nearest central library for information.

Yours faithfully,
ROY D. RATES,
Borough Librarian.

Central Public Library,
High-street,
Acton, W.3.
March 11, 1955.

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METERING PULSATING FLOW

Difficulties of Obtaining Accurate Measurements

SIR, I have read with interest Dr. J. M. Zarek's reply (ENGINEERING, February 25), to my letter of January 21 (ENGINEERING, February 4), but I feel that he has not given a satisfactory answer to the more important points raised.

With regard to the possibility of changes in the mass flow of air when the pulsator is in operation, it is not clear from the author's reply whether the air suction flow to the blower was checked for certain preliminary trials only, or whether this flow was metered for each manometer reading recorded during the course of the investigation. If the latter were the case, Dr. Zarek has done himself an injustice in not mentioning this point in his article. If, on the other hand, the flow was so metered during the preliminary trials only, is the author satisfied that the conditions under which these results were obtained were sufficiently representative of the subsequent trials reported in the article, in particular, when the ratio of orifice diameter to pipe diameter was small?

Dr. Zarek mentions in his article that the pressure head readings in the capacity tank changed when pulsations at the orifice were

superimposed. It would help if he were to give some indication of the order of the maximum change in head as this would be a guide as to the constancy of the mass flow. Dr. Zarek will, I am sure, agree that this information is pertinent, as he himself states that he has become critical of the degree of steadiness of flow produced by rotary blowers.

My suggested explanation of the author's observation that the correction factors became greater than unity when the pulsator was placed downstream of the orifice was based on the argument that there was grave doubt, from the description given in the article, as to whether the mass flow remained unchanged and equal to its steady flow value if pulsations were applied to the stream. I therefore fail to see the relevance of the author's reply to this point in which he quotes vague generalities about pressure amplitudes and phase shift across the orifice.

Although Dr. Zarek denies that he has determined values of the coefficients of discharge under pulsating conditions, he would nevertheless seem to be in some confusion about this since he would not otherwise be able to make such statements as, for example, " the coefficient of discharge was always found to be smaller than for steady flow," etc. It appeared to me that the object of the investigation was to attempt to relate the coefficient of discharge to a non-dimensional number which includes certain quantities characteristic of the pulsating flow. If the purpose of the investigation is merely to " illustrate the approach to the solution of a problem " what is the quantitative value of the article and the results reported in the curves of Figs. 3 to 8?

I raised no " objection " to the form of the pulsations produced by Dr. Zarek's apparatus, but simply pointed out that they did not appear to be of the form with which one normally associates large manometer errors, and that it was therefore dangerous to draw any general conclusion as to whether the manometer indicated the true mean pressure differential across an orifice. Although Dr. Zarek considered only the damping of the manometer liquid in his investigation, I would point out that it can be simply demonstrated that a gauge in which the liquid is damped by means of a small orifice will certainly not indicate the true mean of a pulsating pressure. At the same time I would like to thank Dr. Zarek for providing details of the manometer and the electronic equipment used.

I think I understand the sentiments expressed by Dr. Zarek in the concluding paragraph of his letter, but I am nevertheless of the opinion that the relationships derived between the quantities involved in any investigation, and reported in a scientific paper, should be capable of being understood and applied by the reader of that paper and—more especially when the investigation deals with a method of measurement—due warning should be given of the limitations of the results, particularly when the author of the paper considers that they have only a qualitative or illustrative significance.

Yours faithfully,
T. J. WILLIAMS.

University College of Swansea,
Singleton Park, Swansea.
March 3, 1955.

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NEW POWER STATIONS

The British Electricity Authority has received the consent of the Minister of Fuel and Power to the establishment of a new power station at Blyth, Northumberland. It will have an installed capacity of 480 MW which will be made up of four 120-MW sets that will be supplied with steam from the same number of 860,000-lb. per hour boilers.

Consent has also been received for the construction of a Diesel station, to be known as Machynlleth B, in Montgomeryshire This will contain one 268-kW and three 1,200-kW sets.

AMERICAN ENGINEERING EDUCATION

Proposed Change in Policy

Increasing specialisation and the speed of scientific advance have made the typical pre-war curriculum in engineering education out of date. This is the opinion expressed in a report of a special committee set up by the American Society for Engineering Education to make a new evaluation of the subject. The committee believe that, in future, there must be two broadly distinguished curricula: one for those who will be engaged in production, construction, sale, installation or maintenance of equipment, and the other for professional engineers and scientists, who must be capable of interpreting for design purposes the data provided by research and of themselves advancing the engineering sciences by research. The present average four-year undergraduate programme is considered inadequate to train an engineer to make effective use of the latest scientific discoveries, let alone enable him to make an effective contribution to engineering research.

The two types of curricula recommended by the committee have been called by them the " professional general " and the " professional scientific," both types to include a thorough grounding in mathematics as well as courses in the principal engineering sciences. The latter should, however, go more deeply into physics and chemistry, especially atomic physics and physical chemistry, and should develop courses to make full use of the mathematical background provided. In the " general " course one year of engineering analysis and design will be considered adequate and greater emphasis would be placed on humanistic-social studies. The length of the curriculum would be left to the institution providing the course.

The report, which was adopted at the 62nd Annual Meeting of the A.S.E.E., is the outcome of a two-year study sponsored by the Engineering Foundation and the professional societies that make up the Engineers' Council for Professional Development. The committee which carried out the study consisted of 38 leading educators under the chairmanship of Mr. L. E. Grinter, Dean of the Graduate School at the University of Florida. The full report can be obtained from the secretary of the A.S.E.E., Northwestern University, Evanston, Illinois.

* * *

PRINCIPLES OF AIRCRAFT JET DEFLECTION

Some further background information on the conversion of a Meteor aircraft for research on jet deflectors has been given recently by Westland Aircraft Limited, Yeovil, who carried out the conversion and initial trials under contract to the Ministry of Supply.

The ultimate purpose of devices such as jet deflectors and vertical jets is to provide additional lift for take-off and, more particularly, for landing, which is independent of forward speed, thus eliminating some of the design limitations at present imposed on high-speed aircraft by the necessity for developing adequate lift and control at low speeds.

Since the deflectors are designed in such a way that the jet thrust axis always passes through the centre of gravity of the aircraft, the engines can be rapidly opened up in the event of a balked landing without any change of trim—a point of particular importance to naval aircraft carrying out the exacting task of landing on a carrier deck. There is no additional induced drag arising from the jet lift component, so that a steep initial climb away is possible. The system also provides a sensitive means for controlling altitude and regulating the approach path of the aircraft near the ground.

There are limits to the application of jet deflection on the Meteor aircraft which is designed with conventional aerodynamic control surfaces, the effectiveness of which decreases when the forward speed falls too low. To make the optimum use of direct jet lift, new control methods will have to be adopted—as has, in fact, been done on the Rolls-Royce Flying Bedstead. With the jet deflectors in action on the Meteor, there is some hazard from loss of control in the event of engine failure, and for this reason the initial trials—which were concerned principally with the effects of jet deflectors on control and stability of the aircraft—were all carried out above 3,000 ft. Tests have shown, nevertheless, that using deflectors, with one engine cut and the other developing nearly full power, the Meteor can be controlled at speeds down to 120 knots.

In the experimental Meteor installation, it was necessary to re-position the engines to accommodate the deflector units, and the opportunity was therefore taken to replace the original Rolls-Royce Derwent engines with more powerful Nenes. The jets can be directed by the pilot during flight either through the normal horizontal tailpipe or through a duct giving an effective thrust line at 63 deg. to the horizontal; on this first experimental installation there are no intermediate positions. The deflected jets on the Meteor do not permit an adequate forward speed to be built up for take-off—but, as already mentioned, it was not the purpose of this research to carry out actual landings and take-offs.

In the initial flying trials carried out by Westland Aircraft Limited, with the jet deflectors in action and using 60-per cent. thrust (as on a landing approach), undercarriage down and flaps up, the stalling speed was reduced by some 20 per cent. over that of a normal Meteor. Subsequent trials at the Royal Aircraft Establishment at low altitude, using full power, have shown that it is possible to fly the Meteor at speeds below 70 knots—a reduction of about 40 per cent.

* * *

FINANCING EXPORTS

The facilities of the Export Credits Guarantee Department are not perhaps so widely known in industry as they ought to be. A recent booklet entitled *Payment Secured*, prepared by the Department and the Central Office of Information, therefore performs a useful service in setting out briefly and simply a statement of the facilities offered. This points out that in return for his premium the exporter gets more than insurance—he gets the benefit of the largest and most comprehensive organisation for export-credit management in the country. The files hold dossiers of 100,000 individual overseas buyers, a number which is constantly being supplemented by the work of a large network of inquiry agents. The Department does not, of course itself provide finance for export, but it does make it easier for the exporter to obtain finance from the banking system by reducing each £100 of sales risk to be borne by the exporter to £15, and thus allows more business to be taken against existing capital without overtrading. A policy holder can also make a simple transfer of his rights to his bank and can often obtain a finer discount rate for insured bills which have been thus assigned.

The Department provides short-term policies, under which the exporter may insure the whole of his export trade for twelve months, and medium-term policies, which are suitable for capital goods where the individual contracts are of considerable size and terms of payment extended. Cover can be arranged either from date of contract or date of consignment, but because the nature of the goods and terms of the sale vary so widely, special policies are drawn up for each transaction. It has recently been announced, however, that exporters of some engineering goods such as tractors, large commercial vehicles and light industrial machinery, may now insure the whole of their export trade for 12 months. This service was formerly restricted to exporters of goods for which credit terms did not exceed six months.

AWARDS FOR TECHNICAL WRITING

Radio Industry Council Luncheon

At a luncheon on March 10, 1955, six premiums of 25 guineas were awarded to the authors of articles or groups of articles published in the public technical Press during 1954. The Radio Industry Council premiums for technical writing were first awarded in 1952, and more than one hundred articles from authors connected with 65 firms and establishments have been submitted during the last three years. This year four of the premiums went to authors whose firms were not directly connected with the radio industry; two of these went to the Electronic Office staff of J. Lyons and Company, Limited, Cadby Hall, London, W.14, for three articles on LEO (Lyons Electronic Office). The award winners were Dr. J. M. M. Pinkerton, M.A., Ph.D., Mr. E. J. Kaye, B.Sc. (Eng.), Mr. E. H. Lenaerts and Mr. G. R. Gibbs. Other award winners were Mr. H. S. Jewitt, B.Sc. (Eng.), for two papers on I.F. amplifiers; Mr. J. F. Field and Mr. D. H. Towns for a paper entitled "A Torquemeter for Testing Gas Turbine Components"; Mr. W. R. Cass and Mr. R. M. Hadfield, B.A., for a paper entitled "Dip-Soldered Chassis Production"; Mr. A. E. Maine for two articles on magnetic amplifiers.

Speaking at the luncheon, Mr. P. D. Canning, chairman of the technical directive board, R.I.C., said that the Council had four main objects in view when they instituted the awards. They wanted to stimulate the writing of technical articles, to encourage interest in the technical subjects concerned, to promote good clear writing on technical subjects that could be understood by the layman, and to make known more widely British achievements in radio and electronics. The awards were presented by Mr. G. A. Marriott, vice-chairman of the Radio Industry Council, and Dr. J. M. M. Pinkerton responded on behalf of the guests.

The main objects of the scheme are mentioned above; articles can be submitted for consideration for an award to the R.I.C., but they must first have been published in a paper or periodical at home or abroad which can be bought by the public on bookstalls or by subscription. The article should be concerned with technical developments or practices in radio, television or electronics, and the writer must not normally earn his salary from writing. The scheme is of great value in that it encourages scientists and engineers to make their investigations and techniques readily understood by interested laymen and engineers in other fields.

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THE PUBLIC DEMANDS CLEAN AIR

Sir Hugh Beaver's Lecture

Legislation proposed by a committee must have the support of public opinion if it is to be workable, and the state of mind of the public will greatly influence the reception accorded to a committee's report. This was one of the conclusions drawn by Sir Hugh Beaver in his Calvin W. Rice lecture "Air Pollution: the growth of public opinion," delivered on March 1, 1955, in New York, at the First International Congress on Air Pollution, sponsored by the Committee on Air-Pollution Controls of the American Society of Mechanical Engineers.

Sir Hugh briefly recapitulated the long history of air pollution in Great Britain and of the development of public opinion leading to agitation and action. Much of this agitation and effort was sporadic, disjointed and ephemeral. Throughout the nineteenth century, the great bulk of opinion was either apathetic to the pollution, or definitely hostile to action that would affect either the individual or industry. Throughout that period, numerous committees studied the problem and a good deal of legislation was enacted, but without any material improvement. Sir Hugh contrasted the very different state of feeling at the time of the last two committees of investigation appointed in Great Britain; namely, the Newton Committee in 1920 and the Air Pollution Committee of 1953, of which he was chairman. The public atmosphere affected both the methods of operation of these two committees and the form and nature of their reports.

After the disastrous smog in 1952, public opinion demanded through the Press that action should be taken. The Beaver Committee was set up, and they issued their interim report in November, 1953, which was greeted by a howl of derision from the Press. This was a lot better than no response at all. In November, 1954, the final report was issued and was received with a remarkable chorus of approval. The committee particularly aimed at being clear and emphatic in the expression of their views and in the definition of their recommendations. They were aware that the report was going to be, and ought to be, read by the ordinary newspaper reader, either directly or much more generally by extracts in the Press. They wrote so that the general reader, that was to say the householder, the ordinary business or professional man, and the housewife, could easily understand and grasp what was proposed and why.

Sir Hugh described the report and the legislation proposed, details of which were given in ENGINEERING for December 3, 1954 (vol. 178, page 718). In conclusion, he said that it had often happened before that initial approval of a proposition had broken down into piecemeal criticism and opposition, as the implications had been more closely studied by individual interests. He did not believe that recommendations of this nature would have had the slightest chance of being accepted either by the Government, by industry, by the ordinary householder, or by the public Press 20 years ago, perhaps even 5 years ago. Now, the odds were quite strong that action would follow. It seemed to him evident that this was now the public wish; because at last there had been that growth of public opinion on which everything in the end rested.

* * *

VERY HIGH FREQUENCY BROADCASTING

Inauguration of New Service

The British Broadcasting Corporation announces that the first of its new very high-frequency transmitting stations, using frequency modulation, will be brought into service at Wrotham, Kent, on Monday, May 2, 1955. It will transmit three programmes on frequencies of 89·1, 91·3 and 93·5 megacycles respectively, the effective radiated power in each case being 120 kW and the transmission being horizontally polarised. The station will serve the London area and south-east England within a range of about 50 miles and will reinforce the coverage of the existing medium-wave and long-wave stations, reception of which is becoming difficult owing to interference from foreign stations and the growing use of electrical appliances.

It may be recalled that Wrotham was opened in 1950 as an experimental station with two transmitters to enable the problems of high power very high-frequency transmission and reception to be studied.* The third transmitter will differ from those already in use by being in two parts. These will operate in parallel and each of which will be capable of maintaining the service at reduced power in the event of a fault on the other.

The present experimental transmissions from Wrotham are ceasing until Thursday, April 7, and low-power test transmissions are being made between 9 a.m. and 11 p.m. each day from Alexandra Palace at 93·8 megacycles.

* ENGINEERING, vol. 171, page 151 (1951).

LAUNCHES AND TRIAL TRIPS

S.S. "TEANO."—Single-screw cargo vessel built by Henry Robb, Ltd., Leith, for the Scandinavian trade of Ellerman's Wilson Line, Ltd., Hull. Main dimensions: 260 ft. between perpendiculars by 43 ft. by 24 ft. 9 in. to upper deck; deadweight capacity, about 1,800 tons on a mean draught of 17 ft. Triple-expansion direct-acting reciprocating steam engine, working in conjunction with a Bauer Wach exhaust steam turbine through single-helical reduction gearing. Steam supplied by two multitubular oil-fired boilers. Main engine constructed by Swan, Hunter, and Wigham Richardson, Ltd., Newcastle-upon-Tyne; and the exhaust turbine, gearing and boilers constructed by Barclay, Curle & Co., Ltd., Whiteinch, Glasgow. Speed, 13 knots in service. Trial trip, February 21.

M.S. "SHEAF HOLME."—Single-screw oil tanker, built by Joseph L. Thompson and Sons, Ltd., Sunderland, for the Sheaf Steam Shipping Co., Ltd., Newcastle-upon-Tyne. Main dimensions: 530 ft. between perpendiculars by 71 ft. 10½ in. by 40 ft.; deadweight capacity, about 18,000 tons on a draught of 29 ft. 6 in. Six-cylinder opposed-piston oil engine, developing 7,750 b.h.p. at 103 r.p.m., constructed by William Doxford and Sons, Ltd., Sunderland. Speed in service, 15 knots. Launch, February 24.

S.S. "IERNE."—Twin-screw lighthouse tender and buoy vessel, built and engined by Ailsa Shipbuilding Co., Ltd., Troon, Ayrshire, for the Commissioners of Irish Lights, Dublin. Main dimensions: 180 ft. by 36 ft. by 17 ft.; draught, 12 ft. 11 in. Two triple-expansion steam engines developing a total of about 1,800 i.h.p. Service speed, 13 knots. Launch, February 24.

H.M.S. "JACKTON."—Twin-screw coastal minesweeper, built by Philip and Son, Ltd., Dartmouth, for the Admiralty, London, S.W.1. Main dimensions: 152 ft. by 28 ft. 9 in. by 14 ft. 9 in.; armament, three small guns. Diesel propelling machinery supplied by Mirrlees, Bickerton and Day, Ltd., Stockport, Cheshire. Launch, February 28.

M.S. "POLARPRINS."—Single-screw oil tanker, built and engined by Barclay, Curle & Co., Ltd., Whiteinch, Glasgow, for Hvalfangerselskapet Polaris A/S (Managers: Melsom and Melsom), Larvik, Norway. Last of a series of three vessels built for these owners. Main dimensions: 557 ft. by 73 ft. 9 in. by 40 ft.; deadweight capacity, about 18,300 tons. Barclay Curle-Doxford six-cylinder oil engine, arranged to burn heavy fuel and developing about 8,000 b.h.p. Speed, about 15½ knots. Trial trip, March 4.

S.S. "THESEUS."—Single-screw cargo vessel, built by the Caledon Shipbuilding and Engineering Co., Ltd., Dundee, for the Australian trade of Alfred Holt & Co., Liverpool. Main dimensions: 489 ft. overall by 64 ft. by 35 ft. 3 in. to upper deck; gross tonnage, 7,804; deadweight capacity, 9,650 tons. Three-cylinder cross-compound high-pressure steam turbine, developing a maximum of 8,000 s.h.p. at 112 r.p.m., constructed by Metropolitan-Vickers Electrical Co., Ltd., Manchester. Steam supplied by two Foster Wheeler oil-fired single-furnace boilers, constructed by D. Rowan & Co., Ltd., Glasgow. Service speed, 16 knots. Trial trip, March 5.

M.S. "BLACK PRINCE."—Single-screw vessel, to carry citrus fruits and general cargo, and with accommodation for twelve passengers, built by the Burntisland Shipbuilding Co., Ltd., Burntisland, Fife, for the Mediterranean trade of the Prince Line Ltd., London, E.C.3. Main dimensions: 345 ft. between perpendiculars by 52 ft. 7 in. by 32 ft. 4 in. to shelter deck; deadweight capacity, 4,900 tons on a draught of 21 ft. 9½ in. Hawthorn-Doxford four-cylinder opposed-piston Diesel engine, arranged to burn heavy-fuel oil and developing 3,300 b.h.p. at 110 r.p.m., constructed by Hawthorn Leslie (Engineers), Ltd., Newcastle-upon-Tyne, and installed by the shipbuilders. Trial trip, March 7.

M.S. "SCOTTISH HAWK."—Single-screw oil tanker, built by the Greenock Dockyard Co., Ltd., Greenock, for the Scottish Tanker Co., Ltd. (Managers: Cayzer, Irvine & Co., Ltd.), London, E.C.3. Main dimensions: 543 ft. 3 in. overall by 69 ft. by 38 ft. 6 in.; deadweight capacity, about 16,400 tons on a mean draught of 29 ft. 10 in.; gross tonnage, 11,150. Wallsend-Doxford six-cylinder heavy-oil engine, developing 6,400 b.h.p. at 115 r.p.m. in service, constructed by the Wallsend Slipway and Engineering Co., Ltd., Wallsend-on-Tyne, and installed by Rankin and Blackmore, Ltd., Greenock. Service speed, about 14 knots. Trial trip, March 15 and 16.

Book Reviews

A SYMPOSIUM ON THE GAS TURBINE

Gas Turbine Principles and Practice. By 24 specialist contributors. *George Newnes, Limited, Tower House, Southampton-street, London, W.C.2.* (90*s.*)

At the present stage in the development of gas turbines, anyone writing a book on them must either confine himself to a compact volume dealing with fundamentals or embark on a treatise comparable in magnitude with Stodola's monumental work on steam turbines. Of the former there are several good examples already available and these are entirely adequate as introductory texts for students and for engineers who are coming into this field for the first time. There is certainly room for something more detailed and comprehensive, though some aspects of the subject are not yet ripe for such treatment as there is so little experience and data available. To be successful it is probably essential to divide the work up among several authors because the diversity of subjects is so great that no one person could hope to deal with them all in sufficient detail, and also because it would be impossible to complete the work in a short enough time for it to be reasonably up-to-date—such is still the pace of development. The compilers of the volume under consideration have evidently had these points in mind and have attempted to produce a book which would contain much more information than any of its predecessors.

It is not possible to discuss all the sections in detail; a few of them have, therefore, been selected for comment. The chapter on gas-turbine cycles by Mr. R. E. Wigg does not succeed in its object of familiarising the reader with the variety and possibilities of the various cycles which may be used for the constant-pressure gas turbine. This is due to insufficient care in explaining the fundamentals and the assumptions. On page 2–24, the expression an "exhaust stack loss of 4° C." is quoted. It is not apparent even to one familiar with the subject what this is intended to signify. Perhaps this section might with advantage have been placed after the one on thermodynamics by Dr. E. Glaister and Mr. A. G. Smith, which is admirable. It is particularly welcome to see the emphasis laid on the danger of using *p-v* diagrams for estimating the power output of imperfect cycles. This is a matter which is frequently neglected in text-books on thermodynamics.

Mr. G. B. R. Feilden's section on mechanical design would make an excellent introduction to a book on the subject, but in its present context it does not go into sufficient detail to be really useful. This is to be regretted as the subject has not been dealt with properly in any of the literature, particularly by one so skilled in the art of "kinematic" design as is Mr. Feilden.

The treatment of axial compressors by Mr. A. D. S. Carter is very good. Perhaps in a later edition more could be given on the subject of transonic and supersonic compressors. The centrifugal compressor is a most difficult component to analyse satisfactorily, but much of what can be treated by a combination of theory and practical experience is not very clearly explained by Mr. L. J. Cheshire. Recent American work on the subject is not mentioned. A serious error occurs in the discussion of calculation of velocities in impeller channels on page 6–10, where it is stated that radial equilibrium exists. This is definitely not the case.

Mr. J. Shapiro's discussion of positive-displacement compressors is useful in dealing with a subject which has not been well covered in easily accessible literature, as also is Mr. A. W. H. Jamieson's section on radial-flow turbines—another difficult subject. The gap which exists between the engineer and the metallurgist is not fully bridged by Mr. C. G. Conway in the section on materials, though much useful information is given. It would be helpful if some explanation could be provided about the compositions of various alloys which are referred to by specification number only.

The chapter on steady stresses by Mr. P. H. W. Wolff is commendable, being one of the best arranged and presented in the whole volume. A fair degree of knowledge of stress calculation is assumed, but this is inevitable in a chapter of this length. The references given are very useful, though it would be rather difficult for the general reader to obtain Power Jets reports (incidentally Reference 6 was an R.A.E. report, not Power Jets). Mr. J. R. Forshaw's article on vibration contains a great deal of useful information, but it would be rather difficult for anyone not specialising in the subject to follow it in detail or to make use of it, because so much has had to be packed into a small space.

The sections on fuels and combustion are generally adequate. The technical level is not as high as in some other cases, presumably because of lack of space. In particular, there is little information on the subject of corrosion by heavy-oil ash as opposed to deposition, though this appears likely to be one of the main difficulties in widening the field of application of the gas turbine. Professor O. A. Saunders' and Mr. H. E. Upton's chapter on heat exchangers is accompanied by several useful pictures and diagrams of various examples of this type of equipment. The fact that there is a lack of really good exchangers is nowhere emphasised, yet they are one of the most vital needs of the gas turbine, and one on which its future must greatly depend.

The last chapters deal with the applications of the gas turbine and are written with varying degrees of optimism and imagination. The longest section in the book deals with the application to aircraft (fixed-wing types only) and is unusual in that Mr. R. H. Schlotel devotes a considerable amount of attention to official procedure in specifying, developing and testing engines. But it lacks the directness that comes from first-hand knowledge. The application sections in general are very interesting and will serve as a most useful basis for future discussion of the subjects. Finally, there is a section on educational facilities. Where information is given it is valuable, particularly with reference to industrial training schemes, but the part on technical colleges and universities is uneven and it is difficult to account for some of the inclusions and omissions. Presumably, those who replied to a questionnaire were included. The general appearance and production of the book (except for the binding, which is not strong enough) are pleasing, and there are over 600 illustrations.

A work of this magnitude, written by 24 leading authorities, requires thorough planning and co-ordination if it is to hang together in one piece. This is a formidable task, which in the present instance has not been tackled satisfactorily. It was a sound plan to have a consulting editor, but Sir Harold Roxbee Cox was evidently not consulted sufficiently. There is need of a general editor who can take charge of all the minutiæ involved from the first draft scheme to the final passing for press. This is unexciting but essential work which has been neglected.

The considerable overlapping between sections, though adding perhaps 25 per cent. to the bulk of the book, is advantageous in that it permits of reading any section without much reference to others for essential information. But the lack of a common approach and notation is noticeable. Although a list is given at the end of the book of notation in use at the National Gas Turbine Establishment, there is considerable variation in the symbols used. Four are used for specific heat, and in the thermodynamics section one symbol is used in successive paragraphs for both pressure ratio and the gas constant. The Fahrenheit and Centigrade scales are used more or less indiscriminately in some places, as also are the terms pressure ratio and compression ratio, which is particularly unfortunate when both positive-displacement and aerodynamic compressors are being considered. A standard notation for cycle diagrams would have helped the reader, and the need for competent general editing is also revealed in the frequent misprints. In those sections which give summaries of the historical aspects of the development of the gas turbine, no mention is made of the late George Jendrassik, who did, after all, design and build the first really successful constant-pressure cycle gas turbine.

In reviewing this important volume, it would have been easy but misleading to ignore the fact that a work by a large number of contributors on such a fast-developing branch of engineering requires general planning and editing of unusual ability. That the contributors and the consulting editor have not been served in this way may be due to a number of reasons. It is more than likely that in Britain generally there are far too few scientific and technical editors in relation to the output of new science and technology, and especially in relation to work of such a high calibre as these 24 contributors undertake. Whatever the cause, everyone who uses this book —and no one seriously interested in gas turbines can afford to ignore it—must use his critical as well as his receptive faculties.

The Scientific Basis of Road Design. By F. L. D. WOOLTORTON. *Edward Arnold (Publishers) Limited, 41 Maddox-street, London, W.1.* (60*s.*)

The author of this book has not set out to write a practical treatise on road construction and maintenance, but those road engineers who, like the author, have a considerable knowledge of physics and chemistry may find in it much food for thought. There are other books in the publisher's Roadmakers Library which will help them much more in the practical exercise of their profession, but this one may well broaden their minds.

The book derives much of its inspiration from the work of the soil physics laboratory of the Department of Civil Engineering at Princeton University, and the director of the laboratory, Hans F. Winterkorn, contributes the foreword. In some 340 pages the first 50 are devoted to the physics and chemistry of soils and a further 100 to the kind of things about soils that are found out in the laboratory, such as swelling and shrinkage phenomena. A further 50 pages are devoted to the importance of the clay fraction and the remaining pages to determining the properties of soils and to the various methods of stabilising soils; this section contains much novel and useful data concerning colonial soils, which is the fruit of the author's own experience as a distinguished colonial engineer. Twenty pages only are devoted to what to put on the soil—concrete, asphalt and the like.

Before the war, in some German Universities, candidates for a doctorate prepared a dissertation on the literature of their thesis subject before beginning their own researches. Much of this book would serve as the material for such a dissertation and would thus be of considerable value to any physicist or chemist contemplating almost any research on soil—particularly as the author lists over 300 references, not omitting the more important papers in French and German. The author has collected together a great mass of information about soils and kindred matters, but he has not fully interpreted it in ways the road engineer can understand, nor has he in all cases shown its relevance to the practical problems met in roadmaking in Great Britain. Most of the practical matters discussed are relevant largely to colonial and American soils and methods of road construction.

BOOKS RECEIVED

Some of the books noticed in the Books Received column are selected for extended review in later issues of ENGINEERING.

Measurement of Pressure with the Mercury Barometer. National Physical Laboratory Notes on Applied Science: No. 9. Published for the Department of Scientific and Industrial Research by *H.M. Stationery Office, Kingsway, London, W.C.*2. (1*s.*)

This note has been prepared to assist workers in industry and in research laboratories who are concerned with measuring gas pressures by means of a mercury column. Pressures in the range 0 to 1,200 millibars are dealt with and the accuracy considered is about $\pm 0{\cdot}1$ millibar. In the first section, the fundamentals of pressure measurement are reviewed, and the new international barometric pressure units and standard instrumental conditions, which came into force on January 1, 1955, are defined. This is followed by descriptions of types of barometer and their applications, use, transport and storage. A short description of the test procedure used at the N.P.L. is included.

Applied Geophysics in the Search for Minerals. By A. S. EVE and D. A. KEYS. Fourth edition. *Cambridge University Press, Bentley House,* 200 *Euston-road, London, N.W.*1. (40*s.*)

Methods of geophysical exploration using modern advances in electronics are described in this fourth edition; examples of typical aerial survey instruments, gravimeters and seismic reflection methods are included. Special attention is given to methods of locating deposits of radioactive ores.

Profitable Small Plant Management. By MALCOLM H. GOTTERER. Published by Conover-Mast Publications, Incorporated, and distributed in Great Britain by *Bailey Brothers and Swinfen, Limited,* 46 *St. Giles High-street, London, W.C.*2. (44*s.*)

The author has acted as management consultant for many small firms in America, and this book is intended to help them in all aspects of management. Plant layout, methods improvement, wage incentives, production and materials control, and manpower management are among the subjects discussed.

Abstracts of Papers from the "Journal of the British Institution of Radio Engineers," 1939-1954. *The British Institution of Radio Engineers,* 9 *Bedford-square, London, W.C.*1. (2*s.*)

Abstracts of the principal papers and reports published in the *Journal* of the British Institution of Radio Engineers for the fifteen years, 1939–54. Abstracts are arranged according to the Universal Decimal Classification, and authors are indexed.

The Value of Good Design. A Report on the Scottish Design Congress, Edinburgh, 1954. Edited by ALISTER MAYNARD. *The Council of Industrial Design, Scottish Committee,* 95 *Bothwell-street, Glasgow, C.*2. (2*s.*)

The importance of beauty in the manufactured products with which we surround ourselves is the central theme of this symposium, which discusses, in addition, the steps to be taken in promoting good design, and by whom they should be taken. It is divided into three principal sections based on papers presented by speakers representing companies concerned directly with visual design, the engineering industry, and planning and architectural bodies. Emphasis is laid on the value of visual as distinct from purely technical design, and attention is drawn to the economic, simple, efficient and pleasing character of the "contemporary" approach. The application of new substances is considered, and utility and beauty are shown to be easily reconciled. An appendix of illustrations is provided to give examples of the application of good design to articles as diverse as mirrors, aircraft, magazines and machine tools. Among the members of the Congress were Sir Walter Puckey, President of the Institution of Production Engineers, who spoke on narrowing the gap between artist and engineer, and the Rt. Hon. The Earl of Home, P.C., Minister of State for Scotland, on whose opening speech part of the introduction to the Report is based.

Science and Its Background. By H. D. ANTHONY. Second edition. *Macmillan and Company, Limited, St. Martin's-street, London, W.C.*2. (20*s.*)

The growth of science, its personalities and its place in human affairs form the basis of this treatment of scientific history. Emphasis is placed upon continuity and the historical environment in which discoveries were made; in particular, the contribution of the individual scientist is considered in the light of the growth of science to-day. The applications of science in such fields as medicine and industry are outlined and technological processes are linked with the fundamental ideas from which they have evolved. Period charts divided into synchronous columns under the headings: "action," "knowledge," and "vision" enable various aspects of history to be related in time; and numerous sketches, diagrams and half-tone prints illustrate the text. Dr. Anthony has been a Colonel (Research) in the Royal Army Educational Corps and has also been headmaster of a large grammar school. His book, which in this second edition includes two additional chapters on the post-war utilisation of scientific developments and the pursuit of science for its own sake, not only provides a useful supplement to any formal education but is also of interest to the general reader.

Proceedings of the Scarborough Conference on Smoke Abatement, 1954. *National Smoke Abatement Society,* 30 *Grosvenor-place, London, S.W.*1. (7*s.* 6*d.*)

The reports include a Des Voeux lecture by Sir Edward Salisbury on Air Pollution and Plant Life; an address by Sir Hugh Beaver; a presidential address on the fuel situation by Sir Ernest Smith; a paper on the problem of railway smoke, and papers on the industrial uses of gas and electricity. Discussions on the papers are included.

Some Recent Advances in Tinplate Manufacturing Processes. By W. E. HOARE. *Tin Research Institute, Fraser-road, Perivale, Greenford, Middlesex.* (No price given.)

This booklet of 27 pages consists of a review of the present stage of development of tin-plate manufacturing methods by hot-dipping and the electrolytic process. Detailed diagrams and charts and half-tone illustrations of the processes employed, and of the methods used for testing finished tinplate, are included. The text is a reprint of an address delivered by Dr. Hoare before the 9th International Congress on Packaging, held at Parma, Italy, in September, 1954.

Surveying: Solutions to B.Sc.(Eng.) Examination Questions, London University, External. By D. H. MCPHERSON and P. N. RAY. *Macdonald and Company (Publishers), Limited,* 16 *Maddox-street, London, W.*1. (18*s.*)

Written to assist students, particularly those working without formal tuition, who are preparing for university degree papers or the corporate-membership examination of the Institution of Civil Engineers, this book gives the worked solutions of a number of examination questions grouped under nine headings, including: Instruments and Base-line Measurement; Levelling, Traversing and Tacheometry; Triangulation; Curves (circular, transition and vertical); and Astronomical Observations. Complete solutions are given, as well as a number of proofs of working methods not necessarily required by the question but which will assist the student in the understanding of the problem. Basic theorems are not derived, however, this book being intended to supplement the general textbook on the subject. Some unworked examples, with numerical solutions only, are also included.

Public Cleansing: Refuse Collection and Disposal, Street Cleansing: Costing Returns, 1953-54. Ministry of Housing and Local Government. *H.M. Stationery Office, Kingsway, London, W.C.*2. (4*s.* 6*d.*)

The publication of annual costing returns for public cleansing services was resumed last year with only a summary covering the returns for the year 1952-53. The tables in the latest report are much more complete and have been compiled from returns made by local authorities of the larger urban areas of England and Wales. The statistics are broken down into such figures as weight of refuse collected per 1,000 population, the cost per ton, per 1,000 population and per 1,000 dwellings. Figures are also given for the costs of street and gully cleansing.

Fluid Dynamics and Heat Transfer. By JAMES G. KNUDSEN and DONALD L. KATZ. Michigan University Press. *Oxford University Press (Geoffrey Cumberlege), Amen House, Warwick-square, London, E.C.*4. (36*s.*)

Certain phases of fluid dynamics are fundamental to an understanding of the mechanism of convection heat transfer, and the two subjects are here brought together and related in the one volume. The three main parts of this Engineering Research Institute Bulletin (University of Michigan) cover, respectively: the mechanism of fluid flow, the energy relationships of flowing fluids, and convection heat transfer, and sections are devoted to the heat transfer of liquid metals and flow in tubes of various sections. The analogies of momentum, heat and mass transfer are used to provide theoretical means for correlating data and for predicting one transfer from information about another. For example, in the case of liquid metals it is possible to compute heat-transfer coefficients from velocity profiles by means of the analogy between heat and momentum transfer.

Micrometers: Slide Gauges and Calipers. By ALFRED W. MARSHALL and GEORGE GENTRY. *Percival Marshall and Company, Limited,* 19-20 *Noel-street, London, W.*1. (3*s.*)

A reprint of a well-known book for apprentices and amateurs. It covers the construction and use of these tools.

Fatigue Tests on Rolled Alloy Steels made in Electric and Open-Hearth Furnaces. By P. H. FRITH. Special Report No. 50. *The Iron and Steel Institute,* 4 *Grosvenor-gardens, London, S.W.*1. (25*s.*; 15*s.* to members.)

The detailed results of upwards of 13 years of study of the fatigue problem in relation to high-quality steels are given in this report which was presented and discussed at the last autumn meeting of the Iron and Steel Institute, held in London on November 18, 1954. The proceedings are reported in our issue of December 31, 1954, on page 854. Two main classes of steels were studied, namely, materials heat-treated to an ultimate tensile strength of from 60 tons to 110 tons per square inch, and carbon-chromium type steels heat-treated to a hardness of 750 diamond-pyramid numbers.

Steam, Air, and Gas Power. By WILLIAM H. SEVERNS, HOWARD E. DEGLER and JOHN C. MILES. Fifth edition. *John Wiley and Sons, Incorporated,* 440 *Fourth-avenue, New York* 16, *N.Y., U.S.A.* (6·50 dols.); and *Chapman and Hall, Limited,* 37 *Essex-street, London, W.C.*2. (52*s.*)

A text book suitable for basic courses leading to, for example, National Certificates in Mechanical Engineering and Institution examinations in the theory, practice and equipment of heat engines. The first two chapters are introductory and are followed by one on the principles of thermodynamics; in the subsequent chapters, the general-energy equation has been applied to steady-flow processes. Steam engines have been dealt with in one chapter; centrifugal and axial-flow compressors are included in the discussion of air and gas compression. The material on internal-combustion engines is presented with emphasis on theory and operation rather than on description. Chapters which deal with the gas turbine and industrial refrigeration have been added to those contained in earlier editions.

Materials of Construction. By M. O. WITHEY and G. W. WASHA. *John Wiley and Sons, Incorporated,* 440 *Fourth-avenue, New York* 16, *N.Y., U.S.A.* (9 dols.); and *Chapman and Hall, Limited,* 37 *Essex-street, London, W.C.*2. (72*s.*)

The aim of this book is to provide up-to-date information concerning the sources, manufacture and fabrication of the principal materials of construction. In it are covered their more important mechanical and physical properties, and also the causes and methods of investigating their defects and variations. Modern tests and testing machines are described, and recent statistical data published. Chemical seasoning, wood, cement and concrete, wrought iron, alloy steels and non-ferrous metals are among the construction materials dealt with in detail, and fatigue, heat treatment, and concrete mix design are other subjects discussed. The authors are senior members of the engineering faculties of the University of Wisconsin and their book, which is fully illustrated, is intended for use both as a textbook and a work of reference.

The Story of Tire Beads and Tires. By WALTER E. BURTON. Prepared under the sponsorship of the National-Standard Company. *McGraw-Hill Book Company, Incorporated,* 330 *West* 42*nd-street, New York* 36, *N.Y., U.S.A.* (5 dols.); and *McGraw-Hill Publishing Company, Limited,* 95 *Farringdon-street, London, E.C.*4. (40*s.*)

If the horseshoe-shaped cross-section of a pneumatic tyre is examined it will be seen that its heels or open ends thicken out to form beads; normally, these beads are reinforced with circular strands of wire. In this volume, which is largely a technical handbook, the history of tyre beads, their design, manufacture and applications are fully described in the context of vehicle tyres in general, and comprehensive tables of data together with diagrams and half-tone illustrations supplement the text. Sources of bead trouble, wire and bead testing, and additional uses of wire with rubber are other subjects covered in Mr. Burton's book for which some 20 companies have co-operated in its preparation.

TRADE PUBLICATIONS

Copies of any of the following trade publications are obtainable from the addresses given, though distribution is sometimes restricted.

Railway Equipment. IMPERIAL CHEMICAL INDUSTRIES, LTD., Millbank, London, S.W.1. I.C.I. products for use by railways excluding those specifically for civil engineering and building. Includes: boiler tubes, conductor wires and heat exchangers; light alloys and plumbing services; paints, fabrics and plastics; de-greasing and water-treatment agents, disinfectants and insecticides. Booklet giving brief descriptions of each product and references to other of the company's technical literature.

Mobile Grain Handling Machinery. SIMON HANDLING ENGINEERS LTD., Cheadle Heath, Stockport. Mobile pneumatic grain-handling units made for Turkish Government; each unit designed to receive and discharge at distances up to 100 ft.; capacity 50 tons per hour; auxiliary unit 1 cleans and weighs 50 tons of grain per hour; auxiliary unit 2 weighs at same rate. Illustrated pamphlet with general technical details entitled *Trailers for Turkey*.

Electric Cables. ENFIELD CABLES, LTD., Victoria House, Southampton-row, London, W.C.1. Rubber and thermoplastic cables in accordance with British Standards and Cable Makers' Association formulae. Single, twin, and three-core cables for voltages from 250 to 11,000 with conductor areas from 0·0006 sq. in. to 1·0 sq. in. 112-page catalogue lists types available, and gives specifications and suitable uses.

Contact-facing Metals. METRO-CUTANIT, LTD., Grappenhall, Warrington, Lancashire. "Elmet" metals for facing electrical contacts. Seven alloys varying in hardness from 80 to 450 Brinell and in melting point from 960 to 3,380 deg. C. Available as formed pieces or as sheet. Leaflet gives particulars.

Fork Lift Trucks. HYSTER CO., 2901 N.E. Clackamas-street, Portland 8, Oregon, U.S.A. *How to Operate a Lift Truck*; operation, maintenance, training of drivers, basic materials handling. Booklet illustrated as two-colour cartoon, designed specially for lift truck drivers; available as Form 1214 from company or agents.

Refractory Chart. LAFARGE ALUMINOUS CEMENT CO., LTD., 73 Brook House, London, W.1. Revolving refractory chart showing at a glance various uses for the firm's refractory concrete; the most suitable aggregates to adopt, suggested mixes, and the hot-face temperatures which such mixes should withstand.

Waterborne Diseases. WALLACE AND TIERNAN, LTD., Power-road, London, W.4. *The Waterborne Diseases of Microbiological Origin*, by E. A. Whitlock; paper presented at the Annual Conference of the National Association of Bath Superintendents. Reprinted as company's technical publication No. BRA-183.

Corrosion Prevention. JENOLITE LTD., 13-17 Rathbone-street, London, W.1. Protection of metals; rust proofing and removal, paint bonding by "Jenolizing"; application by brush, spray equipment or tank immersion. Four-page illustrated leaflet.

Calcining Plant. THE POWER GAS CORPORATION, LTD., Stockton-on-Tees. Leaflet, illustrating calcining plant for limestone, dolomite or magnesite. Arrangement diagrams and illustrations of different installations.

"Flit-Plugs." A. REYROLLE & CO., LTD., Hebburn, Co. Durham. Detachable cable-sealing boxes with flameproof entry or "flit-plugs." Flat or round types up to 200 amp. at 6,600 v. Pamphlet No. 756 (revised).

Hermetically-Sealed Meters. RECORD ELECTRICAL CO. LTD., Broadheath, Altrincham, Cheshire. Range of hermetically-sealed ammeters, voltmeters, wattmeters, etc. Resistant to corrosion and fungus attack. Illustrated leaflet.

Rotary Isolators and Earthing Switches. A. REYROLLE & CO., LTD., Hebburn, Co. Durham. Description, installation, operation and maintenance of 33-kV and 66-kV rotary isolators and earthing switches. Booklet I.O.M.S. 419.

Contact Process for Sulphuric Acid. THE POWER GAS CORPORATION, LTD., Stockton-on-Tees. Illustrated leaflet describing plant and manufacture of sulphuric acid by the contact process.

Rock Busters. BRITISH JEFFREY-DIAMOND LTD., Wakefield. B.J-D rock busters. Brief specifications of company's machines. Illustrated leaflet.

The Engineering Outlook—10

TEXTILE MACHINERY

HOPEFUL TRENDS WITH INCREASING DELIVERIES AND IMPROVED MACHINES

The outlook for textile machinery is somewhat brighter than it was a year ago. The order book for some of the traditional types is not perhaps so very greatly improved, but the steady downward trend of the past few years appears to have been arrested. Total output of textile machinery in the year to September, 1954, as may be seen from Fig. 1, was down by about 3 per cent. compared with 1953, and by about 17 per cent. compared with 1952; but, in the third quarter of 1954 (see Fig. 2 page 336) it was substantially above the level of the corresponding quarter of 1953, and is since known to have improved still further. For some sections of the industry, notably those making jute machinery and hosiery, knitting and lace machinery, there has been no fall in activity in the past few years and further increase of their rate of output accounts partly for the recent improvement in the total figure for deliveries of textile machinery. Nevertheless, manufacturers of machinery for the spinning and other processes preparatory to weaving of cotton and wool have also been increasing their activity. Exports account for about 60 per cent. of their output and the most promising feature has been the receipt of some important export orders notably from Russia. This opening up of East-West trade at a time when currency restrictions continue to hamper trade with some of the most important markets is of the highest significance for the future of the British textile machinery industry.

As is shown in Table I (page 337), taken from the *Trade and Navigation Accounts* exports to Brazil, which had reached £5·8 million in 1952, had dwindled to £309,000 in 1954, and exports to nearly all the South American countries, where the potential market is undoubtedly considerable, were all substantially lower than two or three years ago. The Russian contract, which was concluded last May, was for cotton and worsted spinning, weaving and finishing machinery to the value of £7 million and was concluded after months of negotiation. The volume of business to be done in Russia may be very much larger. At one time last year the Russians hinted that they might be willing to place orders worth £22 million. The potential market in the large Chinese textile industry must be even greater, and unless there is further deterioration in the political situation this market may also be expected to open up for British business men within the next few years.

The present rapid rate of increase in population alone should be sufficient to ensure a rising world demand for textiles and hence textile machinery. Unfortunately, this increase is taking place mainly in the Asian and Far Eastern countries and in South America. In all these regions the pressure of population will not produce effective demand for consumer goods or machinery unless adequate capital can be obtained from abroad. The "currency difficulties" which are universally blamed for hampering trade are but a symptom

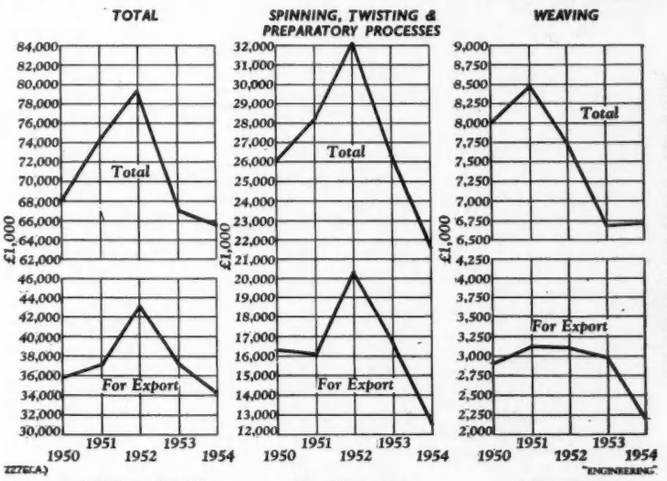
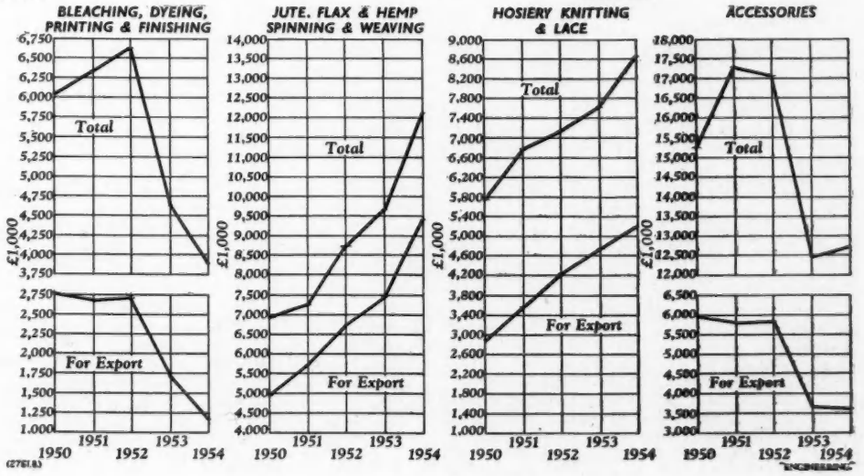


Fig. 1 Delivery of textile machinery for last five years, September to September. The downward trend of recent years seems to have been arrested and the prospects for the future more encouraging than for some time past. The second graph, for Spinning, Testing and Preparatory Process refers to machinery for all work prior to weaving.



of the more fundamental problem of lack of capital. In general, the exploitation of these markets is increasingly likely to require from the textile machinery makers the ability to grant extended credits. Even in such an industrially advanced country as the United States, credit is assuming considerable importance in selling textile machinery. The Universal Winding Company, last March, introduced two schemes which are claimed to be the answer to the problem of modernising textile mills at a time when profits are falling. Under the first, payment for machinery is made out of profits and may be deferred over a period of seven years; under the second, a deposit is paid, and the equipment leased at a quarterly rental over a period of five years at the end of which the company has the opportunity either to buy or to re-lease the equipment.

The distribution of the future markets for textile machinery is less favourable to British manufacturers than formerly. In cotton spinning, for example, with the growth of foreign industries the relative importance of Lancashire is declining; and much of the increase in capacity is taking place in Japan, where there is a large textile-machinery manufacturing industry, and in such markets as India where Japanese competition is likely to be strongest. In India, moreover, there is also a growing indigenous textile-machinery industry. The slow but steady downward trend in deliveries to that market is consequently not surprising. India is, however, still the largest British market for textile machinery, and the volume of deliveries in 1955 should be at least as high as in 1954. The accessories branch of the textile machinery industry has suffered most from the tendency to set up manufacturing facilities overseas, since the simpler types of product can be fairly readily made in even the most backward countries. As may be seen from Table II taken from the *Trade and Navigation Accounts*, the value of exports of accessories in 1954 was well under half the value for 1952.

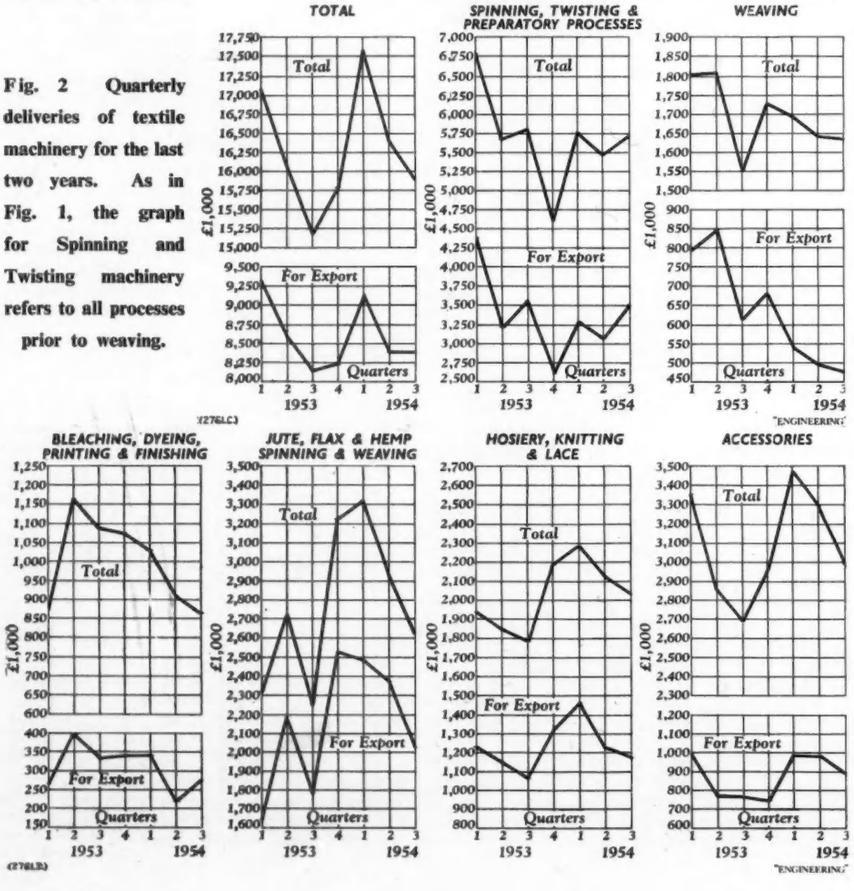


Fig. 2 Quarterly deliveries of textile machinery for the last two years. As in Fig. 1, the graph for Spinning and Twisting machinery refers to all processes prior to weaving.

Fortunately, British manufacturers of textile machinery have been more than holding their own against Japanese competitors. The trend of Japanese exports has been downward since 1952 despite the fact that the pressure of home demand has left manufacturers free to concentrate more upon overseas markets. The Japanese Ministry of Trade and Industry claim that Japanese textile machinery is cheaper than the British without being inferior in quality, and that better delivery can be given. Japanese sales are, however, seriously hampered by inability to give credit, by poor servicing, and by the high cost of spares: Japanese manufacturers themselves believe that the British, with improved deliveries, will recover much of the ground previously lost, particularly in India and Pakistan.

HOME ORDERS IMPROVE

Home orders as well as export, for cotton and wool processing machinery have been improving. At the annual conference of the Cotton Board in October, the chairman, Sir Raymond Street, was able to state that the slowing down of re-equipment which was noticeable in 1952 and 1953, had been checked and that the installation of new machinery which had fallen by about two-thirds had again recovered to the 1951 level. The new orders appear to have been inspired more by the prospect of greater prosperity in the cotton industry than by the incentive of the investment allowance.

Unfortunately, due to Japanese competition and the threat to the home market from imports of Indian grey cloth, confidence in the future has lately fallen off somewhat in Lancashire, and orders for textile machinery may consequently suffer. Activity in the cotton industry is, however, still at a high level and, as Mr. A. R. W. Low, Minister of State, pointed out at a recent luncheon given by the Manchester Chamber of Commerce, the danger from imports of Indian grey cloth is often exaggerated. Of imports of 128 million yards in 1954, 65 million were retained for the home market, or, " only about 4 per cent. of the United Kingdom market of which Lancashire has over 90 per cent. in cloth and 95 per cent. in yarn."

The concern in the cotton industry over the future of the home market is, of course, quite understandable, particularly since exports have been falling steadily—by 70 million yards in 1954 and by over 260 million yards since 1949—and there is undoubtedly a grievance in that, whereas Indian grey cloth is admitted duty-free, British manufacturers are prevented from exporting to India by a prohibitive duty of 60 or 80 per cent. Nevertheless, in view of existing trade agreements and possible international repercussions, it would not be practical or desirable to restrict imports from India. In any case, the main difficulty facing the British cotton industry is shortage of export orders, and the future of the industry depends upon the action taken to produce the goods of the type and quality for which British manufacturers are likely to find ready markets overseas. The pattern of world trade is changing, and Lancashire cannot expect to continue to sell abroad in quantity the cheaper cloths which can readily be made by low-paid unskilled and semi-skilled workers in what were formerly her principal markets.

In India the opportunities are now rather for capital goods which, as Mr. Low pointed out, " make the wealth which tomorrow will buy high quality consumer goods." It is, however, less than just to the Government attitude to suggest as did Mr. Percy C. Fish, chairman of J. F. and H. Roberts, Limited, the textile manufacturers of Manchester, in a recent statement that " The powers-that-be seem to have the idea that in order to get orders for capital goods such as textile machinery, etc., it is necessary to open wide the door into our home trade and Dominion markets for consumer goods such as manufactured textiles on ridiculously advantageous terms." Government action can do little to advance or retard the new trends which, as is argued above, are not even necessarily of advantage to the textile machinery makers, who might well have been able to do a larger volume of business if Lancashire continued to hold its former dominating position as a producer of cotton textiles.

RESEARCH PROGRESS

There is every indication that the market for quality cottons is a growing one, and there is no reason why the British cotton industry should not have a prosperous future provided the accent in re-equipment is on the maintenance of high standards of quality and performance in yarns and cloths. Imaginative research and development programmes are also required in order to stimulate demand through the evolution of new and improved yarns, fabrics and designs. In this, manufacturers already have the advantage of work done by the very active British Cotton Industry Research Association and by the research station of Textile Machinery Makers, Limited, at Helmshore. Hitherto, the deficiency has been not in the volume of research work undertaken, but in the failure of the cotton industry to apply its results.

In the woollen industry the need for " live " research is equally acute, and again the industry is ably served by its own research organisation. Much of the work of the Wool Industries Research Association has lately been devoted to the twin objectives of improving quality and raising productivity. Long and careful studies have resulted in the development of instruments which are now available commercially and have greatly improved the standard of quality control. A carding unit devised by the Association has also done much to improve quality by its excellent control of the levelness of woollen stubbings, which in turn improves the levelness of the yarn. As in all the textile industries, much progress has been made lately in reducing the number of processes. The Ambler Superdraft spinning system, for example, eliminates one or more of the drawing processes by spinning yarns from a sliver 10 times heavier than the normal. The most interesting recent technical development in

the whole field of textile machinery is, however, the Raper Autoleveller [see ENGINEERING, vol. 178, page 600, November 5, 1954]. This enables a constant weight of sliver to be delivered from the combing machine by varying the draft according to the feed weight. In consequence it is possible to cut considerably the number of operations necessary in worsted drawing. Under the established Bradford system the satisfactory production of yarn requires ten operations between comb and spinning frame: with the Autoleveller this is reduced to four for fine counts and three for thicker counts. The machine was invented by Mr. G. F. Raper, of Marsham, who developed it for some years on his own resources before Textile Machinery Makers Limited, took up a licence in 1951. Prince-Smith and Stells, Limited, started work on production models in 1953 and are now in full production.

Expenditure on research and development in the newer fibres is perhaps even greater than in the case of natural fibres. Certainly, the Rayon Research Association has the largest income of all the textile research bodies. The new fibres are complementary to, as well as competitive with, the natural fibres and the future prosperity of the cotton and woollen industries depends in some measure upon the extent to which they can make use of them. Considerable additions to capacity are to take place in the near future. The Terylene plant at Wilton will come into full production in 1955. The extensions recently completed at Pontypool by British Nylon Spinners will enable that plant to achieve its full output of 30 million lb. per annum this year, and the nylon plant in the former British Bemberg factory at Doncaster will start production. The older synthetic fibres have also been making considerable progress: Courtaulds Limited affirmed confidence in their future when they announced last year that they are to increase production of viscose staple by about 50 per cent. by setting up a new plant at Grimsby to produce, in the first instance, about 100 million lb. per annum.

NEW BRITISH HOSIERY MACHINERY

The hosiery industry and, in particular, the nylon stocking manufacturers, will naturally benefit considerably from the expansion in synthetic-fibre capacity. Monthly production of fully-fashioned hose reached 8·3 million pairs in November, 1954, compared with 5·7 million pairs in January, and, despite a large increase in supplies, nylon yarn has still to be rationed. The stocking manufacturers have spent large sums since the war in equipping with the most modern machinery, much of which until fairly recently had to be imported from the United States. Licences for the import of fully-fashioned hose machinery from the United States are still being granted but comparable British machinery is now being made available.

The Hosemaster Machine Company of Huyton, near Liverpool, are producing a six-section machine, capable of knitting a stocking without stopping, which they claim to have a faster rate of production than any other on the market. Mellor, Bromley and Company, have a smaller "Reiner" four-section machine. Their associates, the Bentley Engineering Company, who are already making a 28 division 51 gauge machine and a 12 division 60 gauge machine, expect to put on the market towards the end of the year, a 32 section 60 gauge machine, which should equal in performance the best of the large American machines. This machine is designed to knit 15 denier yarn but can also knit 12 denier, the finest for which demand in the United Kingdom is perhaps likely to be really considerable. A high proportion of output at present is of 30 denier 51 gauge hose, but there is a trend towards the lower 15 and 12 deniers and the finer 60 and 66 gauges. There has also been some development towards 9 denier and 72 to 75 gauge and a Spanish manufacturer, La Constructa Electro Mecanica S.A., is even reported to be producing an 84 gauge machine.

The extent of the popularity of hose of this fineness, however, still remains to be seen. Output of seamless nylon hose is still increasing although not proportionately so much as output of fully-fashioned. It is also retaining popularity in the United States: in this case British machinery is favoured even by the U.S. manufacturers who have lately placed large orders in the United Kingdom. There have been some important developments in recent years in the manufacture of knitting machines for garments other than stockings. The latest recently announced is a machine to knit fully-fashioned underwear or outerwear in wool, cashmere, etc., as well as the natural fibres. This machine, developed by S. A. Monk (Sutton-in-Ashfield), Limited, in co-operation with the Braemar Knitwear Company, is claimed to run at 90 courses per minute compared with 66 or 70 courses on existing machines.

JUTE AND FLAX MACHINERY

The British cotton industry in justification for their plea for a protected home market might well perhaps cite the example of the jute industry. Private imports of raw jute have been resumed but the Jute Control are still responsible for handling British imports of finished jute goods. Imported goods are cheaper than those made in Dundee, but the Jute Control sells them at the price of the home-produced goods. The profit from these operations, which in a full year may amount to £3 million, is thus in effect a measure of the extent to which British consumers are subsidising the jute industry. Some Lancashire manufacturers have been advocating the same protection for the cotton industry in the matter of grey cloth, but the case of the two industries is not parallel. Whereas the export markets are of prime importance for the cotton industry, the jute industry does not even meet the full requirements of the home market, and 40 per cent. of British consumption of jute goods has to be imported. If, therefore, for strategic or other reasons it is considered desirable to have a jute industry in this country, it is essential, as the Government have stated, that the Jute Control should continue its operations "until appropriate measures to safeguard the home industry under conditions conducive to efficiency can be worked out and introduced."

There can certainly be little criticism of the efforts which are being made by the industry to achieve efficiency. A total of £6·5 million has been spent on modernisation during the past eight years. The greatest improvement has so far been made in spinning where productivity has increased by about 25 per cent., but the adoption of automatic devices and the introduction of circular looms will also mean greatly increased productivity in weaving. The drive towards higher productivity includes the erection of new plant: Jute Industries Limited have recently announced that they are to build a new spinning mill in Dundee which will be in production before the autumn of 1956.

Manufacturers of jute machinery have a good volume of export as well as of home orders. The expansion of the jute (as well as of the cotton) industry in Pakistan has provided such a volume of business that Pakistan is now almost as important as India as a market for British textile machinery. Competition from Pakistan is already forcing Indian manufacturers to improve their facilities, and the Indian Jute Mills Association are now reported to have prepared a five-year modernisation plan involving an investment of £37·5 million—including about £7·5 million on particular mill schemes already spent or being spent. British machinery manufacturers should obviously obtain a useful share of orders in this programme.

The linen industry is another of the industries which has suffered somewhat in recent years. Nevertheless, the situation is improving: exports of linen and hemp fabrics in 1954 were at the

TABLE I.—UNITED KINGDOM: EXPORTS OF TEXTILE MACHINERY, BY COUNTRIES.

—	Quantities (1,000 cwt.)			Value (£1,000)		
	1952	1953	1954	1952	1953	1954
Union of South Africa	69	52	43	1,440	1,248	1,023
India	395	313	303	8,668	6,933	6,863
Pakistan	214	194	313	3,189	3,310	5,299
Hong Kong	37	19	13	733	476	334
Australia	68	55	57	1,783	1,614	1,823
New Zealand	17	9	6	420	262	260
Canada	58	32	32	1,438	1,042	1,098
Other Commonwealth Countries	25	26	14	513	596	327
Irish Republic	25	41	34	478	771	696
Finland	24	33	6	613	735	251
Sweden	26	19	9	813	643	360
Poland	23	10	27	420	266	689
Western Germany	54	47	51	1,586	1,616	1,816
Netherlands	59	47	54	1,309	1,180	1,265
Belgium	61	53	38	1,494	1,365	1,043
France	86	75	62	2,514	2,579	2,278
Portugal	40	33	23	879	764	516
Italy	225	151	80	4,625	3,387	1,974
Turkey	98	34	36	1,982	697	815
Egypt	37	21	38	782	523	994
China	22	10	1	498	255	63
United States of America	40	43	25	1,214	1,525	1,017
Mexico	36	33	27	814	809	660
Brazil	265	119	11	5,823	2,637	309
Argentine Republic	24	3	7	722	75	347
Other Foreign Countries	226	211	266	5,692	5,425	7,323
Total	2,254	1,683	1,586	50,442	40,733	39,443

TABLE II.—UNITED KINGDOM: EXPORTS OF TEXTILE MACHINERY, BY MAIN MACHINERY GROUPS.

—	Quantities (1,000 cwt.)			Value (£1,000)		
	1954	1953	1954	1952	1953	1954
New:						
For making synthetic fibres	64	23	23	1,624	709	794
For spinning and twisting and all preparatory processes	1,297	931	932	26,711	20,750	20,906
For processes preparatory to weaving but subsequent to spinning and twisting	61	48	67	1,489	1,319	1,856
Looms and other weaving machinery	358	307	254	5,683	5,267	4,089
Bleaching, dyeing, printing and other finishing	136	111	84	3,098	2,749	2,154
Hosiery and other knitting	50	46	52	4,411	4,610	5,151
All other textile machinery	66	69	60	1,807	2,015	1,908
Accessories, separately consigned:						
Bobbins	14	8	7	611	315	281
Boxes and cans	14	12	10	279	203	154
Card clothing	36	26	18	2,030	1,415	975
Pirn, cones and tubes	13	10	7	340	207	161
Reeds and healds	13	5	5	504	207	183
Shuttles	11	4	5	678	215	242
Second hand	121	83	62	1,177	752	589
Total	2,253	1,683	1,586	50,442	40,733	39,443

rate of 3·93 million yards a month—only 200,000 yards a month less than in 1951, and 400,000 yards a month less than in 1938. In December, moreover, they were running at the rate of 5·0 million yards. In the home market the industry is penalised by the "D" system, since a high proportion of linen products are quality goods upon which purchase tax must be paid. There seems to be a good case for the revision of this scheme, particularly since, as is argued above, the other textile industries are likely to have to turn increasingly to high quality products. The efficiency of production in the linen industry has been increasing by the more extensive use of wet ring-spinning and of auto-doffing wet-flyer spinning. The Linen Industry Research Association have been experimenting with the possibility of obtaining by dry-spinning methods a more regular flax yarn than has hitherto been achieved, and this may have important results in cutting the price of yarns and fabrics.

To sum up: there has been a substantial improvement in the outlook for the textile machinery makers. Export prospects have been brightened by the opening-up of East-West trade, and home prospects by a larger volume of re-equipment orders. The United Kingdom can only continue to pay its way in the world if the best possible use is made of the country's technical knowledge and skill. The textile industries will, therefore, fail in their public duty if, instead of pursuing a dynamic policy of applying the results of the extensive research and development work of their own research organisations and of the textile machinery makers, they oppose change by seeking protection for long-established products and methods. It is to be hoped that the recent quickening in the pace of re-equipment will be maintained.

EARS CAN ASSIST EYES TO INCREASE OPERATORS' ABILITY

METHOD DEVELOPED FOR AIRCRAFT DECK LANDINGS

The use of an audible indication system to convey information which has hitherto been shown on visual indicators is to be introduced into aircraft of the Royal Navy to lighten the pilot's task during approach. Known as Audio, the new system indicates to the pilot, through his earphones, whether his speed is correct without interfering with the voice reception for which the earphones are primarily intended.

Audio has been developed by the Royal Air Force Institute of Aviation Medicine and the Royal Aircraft Establishment mainly for use with the mirror deck-landing aid (described in an article on the Albion published in the October 8, 1954, issue of ENGINEERING).

Using this aid, the pilot's task falls under three main headings: (i) alignment with the centre of the landing lane; (ii) maintenance of the aircraft in the correct height band by reference to the mirror; and (iii) adjustment of the air-speed to within certain narrow limits by visual reference to an air speed indicator, usually placed inside the cockpit.

During the time allowed by present-day approach speeds, the majority of naval pilots would have no difficulty in carrying out these tasks satisfactorily, after suitable practice and under favourable conditions. However, should the conditions become unfavourable, as in bad weather, or the time factor be reduced, as would happen with higher approach speeds, then the story alters. Pilots carrying out the initial trials of the mirror landing aid used artificially high closing speeds. They reported that they experienced difficulty in fulfilling all three of these tasks simultaneously. This resulted in attention being concentrated on two of the tasks to the detriment of the third—usually air speed. It seemed, under these particular conditions, that saturation point in the visual field, was near if it had not already been reached.

An advance appeared to have been made with the advent of the "flashing light" system, which was presented as a reflection on the windscreen. Unfortunately, however, the lights were not always strong enough to be seen in the strongest conditions of sunlight.

EXPERIMENTAL STUDIES

Since little was known about how a pilot employs his eyes while landing, it was decided to conduct a small experiment to see if this could be ascertained. A Meteor 7 jet trainer was used to carry out this experiment. A circular mirror was fitted on top of the starboard coaming in the front cockpit. A 16-mm. cine camera, placed between the two cockpits, was used to photograph the reflection of the eyes of the pilot occupying the front seat. The cine camera was switched on in the rear cockpit by the observer, who was present for all the experimental sorties.

Eleven subjects participated in the experiment. Flying the downwind leg at 400 feet, each one was asked to carry out three circuits and landings. It was explained that the aircraft was to be flown at an accurate airspeed, as near to the approach speed as possible, consistent with safety. The camera was started when the aircraft was turning on its final run in to land.

At the conclusion of each experiment a key was drawn up by photographing each subject's eyes looking, in turn, at the airspeed indicator, engine revolutions counter, altimeter, and compass. The films were then analysed frame by frame.

The results showed two rather surprising things:—(i) the low proportion (56 per cent.) of the approach time that a pilot spent actually looking ahead at the landing strip, when a conventional air-speed indicator was used; (ii) an almost complete suspension of blinking (which should normally occur about once every five seconds) during approach. It was followed by a period of compensatory rapid blinking once the touch down had been made. It is probable that the blink rate can be used as an index of the visual saturation or concentration incurred.

A hint at the possibilities of the auditory sense for relieving this visual saturation was given by one pilot who had flown with the "flashing-light" speed presentation. He noticed that whenever his airspeed transgressed from one speed band to the next, it produced an electrical "click" in his telephones, which was clearly audible; he used this click as a cue to refer to his airspeed.

Following exhaustive tests a system of coded signals was selected which could convey to a pilot a fairly accurate reading of his airspeed. Certain principles were laid down in selecting the code, among which were: (i) the signals must be distinctive from other noises likely to be heard; (ii) they should be able to be interpreted through normal speech; (iii) they should be capable of conveying any airspeed trend accurately throughout a fairly wide speed band (about 30-35 knots); and (iv) as long as the approach speed was correct, the signal should not be distractive; therefore, a pure continuous note was chosen. When the speed was outside the correct approach band, the signals should be warning and attention-getting.

A laboratory experiment was carried out to ascertain the merits of the auditory presentation as compared with two other airspeed presentations, namely, the flashing lights, and a conventional airspeed indicator. By means of a cam the airspeed value was caused to vary about its datum value, and could be restored or neutralised by a lever (comparable to a throttle) held by the subject's left hand. The subject followed one presentation at a time. Simultaneously he was asked to follow a tracking task not dissimilar to that of deck-landing. Here, he aimed to keep a spot of light, moving vertically up and down, in alignment with datum lights. He did this by means of a control column held in his right hand. This, in fact, was similar to the presentation of the mirror landing aid. All the errors were measured automatically for both tasks.

Forty-eight subjects (half of them pilots) were taken. Of these, 26 gave the most accurate performance when the audio airspeed was used, 15 when the flashing lights were used, and only five were best on the conventional indicator.

A prototype audio airspeed was constructed and installed in a Sea Hawk, and further extensive air trials have been carried out, including deck landings in H.M.S. Albion, using the mirror landing aid. The system has been tried by approximately 35 pilots, and their reports give a clear indication of the efficacy of the system. The code is simple, and can be learnt in a few minutes.

As a matter of convenience the signals are only heard in the pilot's headphones when he is below the maximum speed for lowering his undercarriage and flaps. Above this speed there is silence. The apparatus is particularly pleasant to use during a ground control approach, as the signals can be heard as an informative background to the controller's instructions.

The apparatus is relatively simple, and is accurate to within a quarter of a knot. It is made in two separate parts, each of which, in the production versions, will fit into two boxes similar to an elongated altimeter casing. These can then be put anywhere in the aircraft. One of the two parts consists of a "sensing" unit to be attached to the pitot head (if airspeed is the information required); the other is the sound-producing box, consisting of a "two-note organ" working on the same principle as an electric organ. Serviceability of the prototype equipment has been 100 per cent. to date.

A camera was installed in the Sea Hawk in place of the gun sight to record eye movements of pilots. As the result of this, two features emerged during approaches and landings: (i) using the audio airspeed, very few visual references were made to the conventional airspeed indicator, once confidence in the system had been established; (ii) pilots resumed a normal rate of blinking during the approach, and appeared to have more time to look around.

A further advantage of the audio airspeed is that the signals can be transmitted by one of the aircraft's radio sets not in other use at the time. Thus, in training, a check can be made by instructors on the approach speeds of pupils, and in routine landings, controlling officers can check on the airspeed of an approaching aircraft. Those aircraft that are approaching too fast for the arrester gear to handle can be "waved round" by normal voice control.

The controls for the pilot consist of a normal "on/off" switch combined with a rheostat volume control. In addition, in the earlier production models, there will be a three-position selector to move the datum of signals for aircraft landing considerably under or over the normal landing weight.

This selector would be omitted should the audio system be used at some future date to indicate angle of attack, instead of air speed. Work is now in hand to put this principle into practice.

★ ★ ★

We regret that a printing error occurred in the article "Running-in an engine" which appeared on page 270 of the issue of March 4. The first three lines of the last paragraph in the first column should read: "They then described engine tests which confirmed these findings, and summarised their observations by saying that for 'unhardened . . . . etc.,'" the quotation ending at the words "additive oils".

THE ENERGY THEOREMS OF STRUCTURAL ANALYSIS

2—DERIVATION AND DISCUSSION OF THE THEOREMS

By E. H. Brown, PH.D., B.SC.(ENG.), D.I.C.*

The first part of this article, "Definitions and Fundamentals," was published in our issue of last week. This second part derives and discusses nine energy theorems applicable to structural analysis. Their use will be illustrated by worked examples in Part 3 to be published subsequently.

The mathematical operations in the discussion of the energy theorems which follows are few, and it may be worthwhile to list the purely mathematical definitions and propositions first, referring back to them as required.

A: $\frac{\partial F}{\partial P_s}$ implies that F is an expression in terms of the loads P_r but not of the displacements Δ_r, nor of the statically-determinate support, and that in the differentiation with respect to one of the loads P_s all the other forces, P_r, are held constant.

B: $\frac{\partial F}{\partial \Delta_s}$ implies that F is an expression in terms of displacements Δ_r but not of the loads, and that in the differentiation with respect to one of the displacements Δ_s all the other displacements, Δ_r, are held constant.

C: If F is an expression in terms of several variables x_r

$$dF = \sum_r \frac{\partial F}{\partial x_r} dx_r.$$

D: $$\frac{d}{dX}\left\{\int_0^X F(x)\,dx\right\} = F(X).$$

E: If $F(\Delta)$ is a continuous function of Δ it has a stationary value when $\frac{dF}{d\Delta} = 0$ which is a minimum when $\frac{d^2F}{d\Delta^2}$ is positive, a maximum when $\frac{d^2F}{d\Delta^2}$ is negative.

F: $$\frac{\partial}{\partial P_s}(FG) = G\frac{\partial F}{\partial P_s} + F\frac{\partial G}{\partial P_s};$$

in particular,

$$\frac{\partial}{\partial P_s}\sum_r P_r \Delta_r = \sum_r \frac{\partial}{\partial P_s}(P_r \Delta_r) = \Delta_s + \sum_r P_r \frac{\partial \Delta_r}{\partial P_s}.$$

G: $$\int_0^X y\,dx + \int_0^Y x\,dy = XY.$$

The proofs of C, D, E, F and G are to be found in textbooks on the calculus (for example, reference 4); A and B are simply definitions.

CASTIGLIANO'S THEOREM OF EQUILIBRIUM

We have seen that, for the conservation of energy of an elastic structure which is subjected to external forces at several points r,

$$U = U_0 + \sum_r \int_0^{\Delta_r} R_r(\delta_r, \Delta_r, \Delta_s, \ldots)\,d\delta_r$$

a function of U_0 and the displacements Δ_r only. Suppose that, by suitable infinitesimal adjustments to all the forces, the displacement Δ_s is increased to $\Delta_s + d\Delta_s$ and all the other displacements Δ_r remain unchanged. Then the increase in strain energy will be $\frac{\partial U}{\partial \Delta_s} d\Delta_s$.

We now find a second expression for this increase. It must have been contributed entirely by an addition to the area under the reaction/displacement curve for s, shown in Fig. 5, since all the other points r were stationary, as depicted in Fig. 6. (Note the discontinuity in the curve of Fig. 5; this is because when δ_s exceeds Δ_s the displacements Δ_r are no longer all increasing together). If $d\Delta_s$ is infinitesimal, the total increase in U is therefore $R_s(\Delta_s)\,d\Delta_s$. Hence

$$\frac{\partial U}{\partial \Delta_s} = R_s(\Delta_s)$$

or strictly,

$$\frac{\partial U}{\partial \Delta_s} = R_s(\Delta_s, \Delta_r, \ldots).$$

For equilibrium at s, $R_s(\Delta_s)$ must equal $P_s(\Delta_s)$, $= P_s$, the load actually applied. Then

$$\frac{\partial U}{\partial \Delta_s} = P_s. \quad . \quad . \quad . \quad (8)$$

This is Castigliano's theorem, expressing equilibrium of an elastic structure, and it is independent of the shapes of the reaction/displacement curves. Note that we have considered U to be expressed as a function of the displacements of loaded points only; actually there need be no limit to the number of independent displacements used, provided the displacements are "compatible," that is, provided the displacement in one direction of any one point of the structure is not expressible in more than one way. This is because an unloaded point may be considered as subjected to an unspecified load P_r, so that $\frac{\partial U}{\partial \Delta_r} = P_r$, and this is still true for the particular value $P_r = 0$.

The theorem may therefore be stated thus: *If the strain energy of any elastic structure is expressed in terms of the displacements of a number of points of the structure, then the differential coefficient of the expression with respect to the displacement of one of the points gives the component force acting at that point in the direction of the displacement.*

The use of this theorem will be illustrated in example 1 of Part 3.

THEOREM OF VIRTUAL WORK

Let the strain energy U of an elastic structure, in equilibrium under a system of external loads P_r and appropriate statically-determinate supports, be expressed in terms of the displacements Δ_r only. By proposition C, the increase in U accompanying arbitrary infinitesimal increases in the displacements is

$$dU = \sum_r \frac{\partial U}{\partial \Delta_r} d\Delta_r.$$

These increases are produced, of course, by small increases in the applied loads, the overall equilibrium of the structure being maintained by adjustments to the statically-determinate supports. We have seen that for equilibrium at each loading point $\frac{\partial U}{\partial \Delta_r} = P_r$, so that

$$dU = \sum_r P_r\,d\Delta_r. \quad . \quad . \quad (9)$$

This gives the theorem stating that: *The increase in strain energy of a loaded elastic structure due to a virtual infinitesimal deformation from its equilibrium position is equal to the work done by the external forces during the deformation.*

The theorem is true for any shapes of the reaction/displacement curves, and its effect is to define the equilibrium position of the structure. That is, like the previous theorem, it expresses equilibrium in terms of the displacements.

This definition is sometimes given with the fall in potential energy of the forces substituted for the work done by them. It is of course the same thing. Applying propositions B and D to equation (2), Part 1, page 306.

$$\frac{\partial V}{\partial \Delta_r} = -P_r(\Delta_r) = -P_r$$

so that

$$dU = -\sum_r \frac{\partial V}{\partial \Delta_r} d\Delta_r \quad . \quad . \quad (10)$$

and it is customary then to write the R.H.S. as $-dV$, the fall in potential energy. This may lead to trouble. For consider the case of constant loads, for which $V = V_o - \sum_r P_r \Delta_r$. The unwary, remembering that the virtual displacements could only be produced by increased forces, may be tempted to interpret proposition F as giving

$$dV = \sum_r \frac{\partial V}{\partial \Delta_r} d\Delta_r + \sum_r \frac{\partial V}{\partial P_r} dP_r = -\sum_r P_r\,d\Delta_r - \sum_r \Delta_r\,dP_r$$

in which $dP_r \neq 0$. For this reason the writer prefers to leave the theorem in one or other of the forms of equations (9) and (10).

An illustration of the use of Virtual Work will be given in example 2 of Part 3.

THEOREM OF MINIMUM TOTAL POTENTIAL ENERGY

The total potential energy of a system is defined as the sum of the potential energy of the external forces, V, and the strain energy of the structure, U. For an elastic structure under several loads we have seen that $\frac{\partial U}{\partial \Delta_s} = R_s(\Delta_s)$, and hence, from propositions B and D and from equations (2),

$$\frac{\partial}{\partial \Delta_s}(U + V) = R_s(\Delta_s) - P_s(\Delta_s)$$

so that if Δ_s is the displacement which gives equilibrium of R_s with P_s,

$$\frac{\partial}{\partial \Delta_s}(U + V) = 0. \quad . \quad (11)$$

Then proposition E asserts that $U + V$ is a

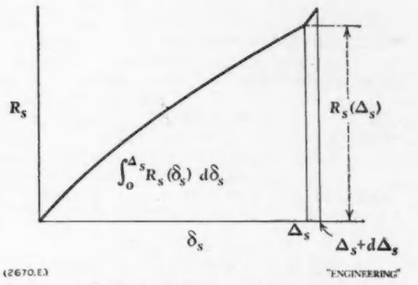


Fig. 5 If all the loads on an elastic structure are adjusted by infinitesimal amounts such as will keep all the loading points stationary except s, the increase in strain energy U is $R_s(\Delta_s)\,d\Delta_s$.

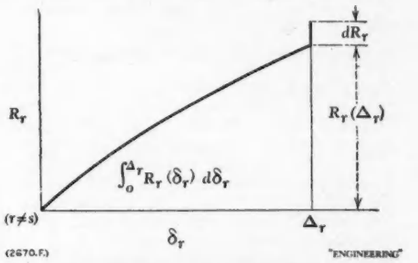


Fig. 6 At loading points other than s there is no change of displacement during the adjustments referred to in Fig. 5. Thus $R_r(\Delta_r)$ may increase by dR_r, but no work is done on the structure at r.

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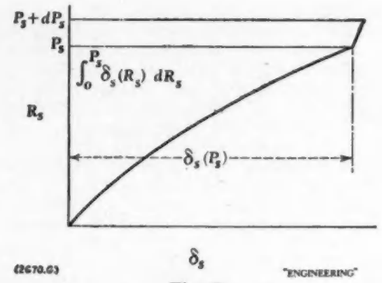

Fig. 7

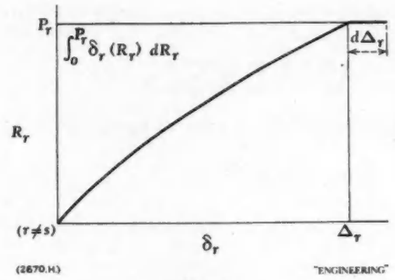

Fig. 8

Figs. 7 and 8 These two figures for complementary energy correspond to Figs. 5 and 6 for strain energy. This time, however, the only load to be increased is that at *s*, and in general all the loading points will move. Fig. 8 shows that for loading points other than *s* the area above the reaction/displacement curve is unchanged, so that the total change in complementary energy S is given by the increase in area in Fig. 7, which is $\delta_s(P_s)dP_s$.

minimum with respect to variations of Δ_s if $\frac{\partial^2}{\partial\Delta_s^2}(U+V)$ is positive.

$$\frac{\partial^2}{\partial\Delta_s^2}(U+V)=\frac{\partial R_s(\Delta_s,\Delta_r,\ldots)}{\partial\Delta_s}-\frac{dP_s(\Delta_s)}{d\Delta_s},$$

the difference between the rates of increase of the reaction and the load. If the load is increasing faster than the reaction we shall find that after the slightest further increase of Δ_s, $P_s > R_s$, and the displacement will continue to grow. For stable equilibrium we must have

$$\frac{\partial R_s(\Delta_s)}{\partial\Delta_s}>\frac{dP_s(\Delta_s)}{d\Delta_s}$$

so that $\frac{\partial^2}{\partial\Delta_s^2}(U+V)$ is positive, and the reaction increases faster than the load.

Thus the theorem states that: *The condition for stable equilibrium of a loaded elastic structure is that the sum of the potential energy of the external forces and the strain energy, expressed only in terms of the displacements of a number of points of the structure, shall be a minimum with respect to variations of those displacements.*

As in the previous theorem, there is no restriction on the number of independent displacements involved, nor on the shapes of the reaction/displacement curves.

It is sometimes convenient to express U and V in terms not of the displacements Δ_r, themselves, but of an equal number of other quantities a_p from which the displacements may be found. Then

$$\frac{\partial}{\partial a_p}(U+V)=\sum_r\frac{\partial}{\partial\Delta_r}(U+V)\frac{\partial\Delta_r}{\partial a_p}=0$$

by proposition C, and as varying the quantities a_p is to vary the displacements Δ_r, this stationary value must be a minimum; for if the correct values of Δ_r make $(U+V)$ a minimum, so must the correct values of a_p.

Example 3 of Part 3 will illustrate the method of applying this theorem.

FIRST THEOREM OF COMPLEMENTARY ENERGY

If an elastic structure is in equilibrium under several applied loads, S is given by equation (5) as

$$S=S_0+\sum_r\int_0^{P_r}\delta_r(R_r,P_r,P_s,\ldots)\,dR_r$$

a function of S_0 and the forces, P_r, only. If one of the forces, P_s say, is increased to P_s+dP_s, the others remaining constant, the complementary energy will increase by $\frac{\partial S}{\partial P_s}dP_s$ (proposition A).

We now find a second expression for this increment. All the points *r* will move, but the increase in S must be accounted for solely by an increase in the area above the displacement/reaction curve for *s* as shown in Fig. 7, for there is no increase in the area above the other curves, Fig. 8. If dP_s is infinitesimal, the total increment to S is therefore $\delta_s(P_s)\,dP_s$, and

$$\frac{\partial S}{\partial P_s}=\delta_s(P_s)=\Delta_s. \qquad (12)$$

In this argument we have increased P_s by dP_s and held all other external loads constant, but some reservation is necessary. For if *all* the external forces save P_s were unaltered the force dP_s would be unbalanced, and the structure would accelerate. The statically-determinate supports must therefore be allowed to vary in order to maintain equilibrium, and before partially differentiating with respect to P_s it is essential to eliminate them from the expression for S by means of the equations of overall equilibrium.

Equation (12) gives the first complementary energy theorem, and once again it is independent of the shape of the reaction/displacement curves. The theorem states that: *If the complementary energy of any elastic structure is expressed in terms of the external loads but not of the statically-determinate supports or the displacements, then its partial derivative with respect to one of the applied loads gives the displacement of that load in its own line of action.*

See example 4 of Part 3.

CASTIGLIANO'S THEOREM FOR LINEAR STRUCTURES

We define a linear structure as one with a linear reaction/displacement law, so that

$$U=U_0+\tfrac{1}{2}\sum_r P_r\,\Delta_r$$

where, as previously, P_r is the load actually applied and equal to $R_r(\Delta_r)$. It is not sufficient for the stresses and strains to have a linear relationship; structures with large deflections but small strains, and structures where even a small change in the configuration greatly affects the action of the forces (for example, eccentrically loaded struts) may have linear stress/strain relationships but non-linear reaction/displacement characteristics.

It was shown in the theorem of Virtual Work that if an elastic structure is given an infinitesimal deformation from its loaded equilibrium position by means of infinitesimal increases to the loads, the increase in strain energy is $dU=\sum_r P_r\,d\Delta_r$ [equation (9)]. Then, if the only load to be increased except for the statically-determinate supports is P_s, we have from proposition C, $dU=\frac{\partial U}{\partial P_s}dP_s$ and $d\Delta_r=\frac{\partial\Delta_r}{\partial P_s}dP_s$, so that

$$\frac{\partial U}{\partial P_s}=\sum_r P_r\frac{\partial\Delta_r}{\partial P_s}.$$

For a linear elastic structure $U=U_0+\frac{1}{2}\sum_r P_r\,\Delta_r$, and by propositions A and F,

$$2\frac{\partial U}{\partial P_s}=\Delta_s+\sum_r P_r\frac{\partial\Delta_r}{\partial P_s}.$$

Subtracting these two equations, we have

$$\frac{\partial U}{\partial P_s}=\Delta_s. \qquad (13)$$

The expression for U, which is in terms of the loads only, must not be in terms of the statically-determinate supports for the same reason as was discussed in the preceding theorem.

Equation (13) can alternatively be derived from equation (12). For when all the reaction/displacement curves are linear, $S\equiv U$ (*cf.* Fig. 4). Equation (12) then becomes immediately

$$\frac{\partial U}{\partial P_s}=\Delta_s.$$

Castigliano's theorem for linear structures states that: *If the strain energy of a linear elastic structure is expressed in terms of the external loads, but not of the statically-determinate supports or the displacements, then its partial derivative with respect to one of those loads gives the displacement of the load in its own line of action.*

As the structure is a linear one the effect of self-straining may be ignored in computing U. The procedure in using the theorem is demonstrated in Part 3, example 5.

MINIMUM STRAIN ENERGY THEOREMS—1

Let an elastic structure be given certain specified displacements at points *r* by means of suitable forces P_r balanced by the statically-determinate supports. We saw in our first theorem that if U is expressed in terms of the displacements of these and other points of the structure, $\frac{\partial U}{\partial\Delta_i}=R_i(\Delta_i)=P_i$ for equilibrium at *i*. $\frac{\partial^2 U}{\partial\Delta_i^2}=\frac{\partial R_i}{\partial\Delta_i}$, the rate of increase of the reaction with increase of displacement, which is essentially positive. Then, by proposition E, if *i* is not one of the points *r*, U is a minimum with respect to variations of Δ_i if $P_i=0$; i.e., if *i* is unconstrained.

The first theorem of minimum strain energy may now be stated as follows: *If certain points of an elastic structure are given specified displacements the strain energy is least when the remainder of the structure is unconstrained.*

Like the one from which it is derived this theorem is independent of the shape of the reaction/displacement curves. (In references 1, 5 and 6 the theorem is given and proved as for structures with linear reaction/displacement relationships only, although Williams in reference 6 mentions a physical proof by Lamb which is clearly valid for non-linear cases).

The theorem may alternatively be stated differently: *Of all the configurations which may with compatibility of displacements be assumed by an elastic structure which is subjected to specified displacements at certain points but is unloaded elsewhere, the one which satisfies the conditions of equilibrium will make the strain energy a minimum.*

For if the strain energy is not a minimum with respect to variations of Δ_i, for example, $\frac{\partial U}{\partial\Delta_i}=R_i(\Delta_i)\neq 0$, and if *i* is to be an unloaded point, the condition of equilibrium is violated.

Derived in this way this theorem is clearly closely related to the theorem of minimum total potential energy (for $\frac{\partial V}{\partial\Delta_i}=0$ if there is no external load at *i*) and it may be extended to give $\frac{\partial U}{\partial a_p}=0$ in the same way. Example 6 of Part 3 illustrates the method of application.

MINIMUM STRAIN ENERGY THEOREMS—2

Consider a simply-supported linear elastic structure in equilibrium under certain specified forces at points *r* and an unspecified force at a point *i*. By Castigliano's theorem for linear structures, if U is expressed in terms of the forces P_r and P_i, $\frac{\partial U}{\partial P_i}=\Delta_i$. When $\Delta_i=0$, $\frac{\partial U}{\partial P_i}=0$, and U is stationary with respect to variations of P_i; also $\frac{\partial^2 U}{\partial P_i^2}=\frac{\partial\Delta_i}{\partial P_i}$ (the rate of increase of Δ_i with increasing P_i, which must be

positive) and it follows from proposition E that the stationary value is a minimum.

A constraint P_i for which $\Delta_i = 0$ is normally known as a rigid redundant support. Hence the theorem states that: *A rigid redundant support to a linear elastic structure under specified loads takes such a value as will make the strain energy a minimum.*

P_i was considered as a constraint, so we take its positive direction as opposed to the direction Δ_i takes when $P_i = 0$. Thus $\frac{\partial U}{\partial P_i}$ $(P_i = 0)$, which is equal to $\Delta_{i(P_i=0)}$, is negative, for positive Δ_i must have the same direction as positive P_i. Then, as the constraint is applied, that is, P_i increases from zero, U is diminished, and continues to be diminished until P_i attains such a value as will make Δ_i zero, when $\frac{\partial U}{\partial P_i} = 0$. The value of U when the structure is constrained to make Δ_i zero is therefore less than the "unconstrained" value when $P_i = 0$. This property led Williams[6] to speak of the Maximum Strain Energy principle for unconstrained structures, but it is perhaps an unfortunate term, inasmuch as the strain energy is not stationary $\left(\frac{\partial U}{\partial P_i} \neq 0\right)$ in the unconstrained configuration, but would continue to increase with further displacements. See Part 3, Example 7.

MINIMUM STRAIN ENERGY THEOREMS 3—LEAST WORK

Structures for which the stresses cannot all be found in terms of the applied loads by using only the principles of equilibrium are called "redundant" structures. The stresses in certain structures which are properly of this type, however, can sometimes be found approximately by a combination of equilibrium conditions and the assumption that cross-sections initially plane remain so after loading (for example, many types of beam), and where this approximation is satisfactory the structure need not be considered redundant.

The stresses in a redundant structure can all be expressed by the principle of equilibrium (and, possibly, the "plane-sections" assumption) in terms of the external loads P_r and a number of internal loads, moments or stresses Q_i at particular points *i*. When their number cannot be reduced by further applications of the equilibrium principle, the internal forces, Q_i, are called the "redundancies," and this minimum necessary number of them "the degree of redundancy of the structure." Redundant pin-jointed frames and (using the plane sections assumption) continuous frames, portals and such-like, will have one or more redundancies; two-dimensional plate problems will have a doubly-infinite number, and general three-dimensional bodies even more.

It is this ability of a redundant frame to maintain equilibrium for any set of independent values of P_r and Q_i that makes self-straining possible, for the structure can hold a stress-system derived from the redundancies Q_i, when all the forces, P_r, are zero.

Consider a linear elastic redundant structure. Here the strain energy also can be expressed in terms of the forces P_r and redundancies Q_i by integrating such terms as $\frac{1}{2}\sigma_x \epsilon_x dx\,dy\,dz$ throughout the volume of the structure. Let a "cut" be made at the section of action of each redundancy Q_i which would release Q_i while still allowing any moments or forces in other directions to act at the section. (If Q_i is a moment, we use a hinge; if a force, we must use a tongue-and-groove joint; if it is the stress on an element, we must use our imagination.) Starting with our cut structure unloaded, we apply the forces P_r, and also pairs of equal and opposite external forces Q_i to the two sides of each cut. When the sides of the cuts just meet the forces Q_i will have the redundancy values.

We digress here to extend Castigliano's theorem for linear elastic structures, treating the case when two of the external loads, P_s and P_t, are equal and vary together. Repeating the previous argument, we find

$$\frac{\partial U}{\partial P_s} = \sum_r P_r \frac{\partial \Delta_r}{\partial P_s}$$

as before, but, by proposition F,

$$2\frac{\partial U}{\partial P_s} = \Delta_s + \Delta_t + \sum_r P_r \frac{\partial \Delta_r}{\partial P_s}$$

giving

$$\frac{\partial U}{\partial P_s} = \Delta_s + \Delta_t. \quad . \quad . \quad (14)$$

We note also that $\frac{\partial^2 U}{\partial P_s^2} = \frac{\partial \Delta_s}{\partial P_s} + \frac{\partial \Delta_t}{\partial P_t}$, since P_s and P_t increase together, and both terms on the R.H.S. are essentially positive.

First consider a structure without initial self-straining so that the unloaded cut structure has no gaps at the cuts. If the displacement of one of the forces at a cut *j* is Δ_j when the forces P_r and Q_i are applied, then the other force Q_j, an opposing one, must move $-\Delta_j$ in its own line of action, to give compatibility of displacement at *j*. Using the theorem just proved, since the sum of these displacements is zero,

$$\frac{\partial U}{\partial Q_j} = 0. \quad . \quad . \quad (15)$$

Furthermore, $\frac{\partial^2 U}{\partial Q_j^2}$ is positive, so that proposition E gives U to be a minimum with respect to variations of Q_j.

This is the theorem of Least Work, stating that: *Of all the stress distributions in an initially unstressed linear elastic structure which will maintain internal equilibrium and balance the externally applied loads, the one which will also allow compatibility of displacements makes the strain energy, expressed as a function of the external loads and redundancies only, a minimum.*

Instead of expressing U in terms of the *n* redundant forces themselves, it is sometimes convenient to express it in terms of some other *n* quantities a_p from which the values of the forces Q_i may be found. Then the forces Q_i can be varied by varying the quantities a_p, and as the correct values of the forces Q_i make U a minimum the correct values of the quantities a_p must do so also. Hence the more general theorem of Least Work, stating that: *If an initially unstressed linear elastic structure has n redundancies, and by using all the conditions of internal and external equilibrium its strain energy is expressed in terms of the external loads and n other quantities a_p from which the redundancies may be found, then the conditions for compatibility of the displacements are the n equations* $\frac{\partial U}{\partial a_p} = 0$.

Consider now a structure with initial self-straining. Before the forces P_r are applied there are stresses due to the redundancies Q_i, and when the cuts are made, reducing all stresses to zero, the structure will "spring." That is to say, there will be relative displacements λ_i of the two sides of each cut. As before, we apply pairs of equal and opposite external forces Q_i, this time without the forces P_r, and when the gaps are all just closed the redundant forces Q_i will have attained the initial redundancy values. Taking the direction of Q_j as positive when the force is tending to close the gap at *j*, the sum of the movements of the two opposing forces at *j* is λ_j; thus

$$\frac{\partial U_0}{\partial Q_j} = \lambda_j. \quad . \quad . \quad (16)$$

This gives the theorem for self-strained structures: *If the strain energy of an unloaded self-strained linear elastic structure is expressed in terms of the n redundancies only, then its partial derivative with respect to a redundancy Q_j gives the dislocation which would occur at j in the line of action of Q_j if cuts were made in the structure, one at the point of action of each redundancy, so as to release all the self-straining.*

There will be as many equations of this type as redundancies, and thus a knowledge of the dislocations λ_i—the "initial lack of fit" of the structure—is sufficient to determine the redundancies Q_i and hence the complete stress distribution due to self-straining. The external loads P_r can be considered separately; the theorem applies only to linear elastic structures, for which we have seen that the stress systems due to external loads and self-straining are mutually independent.

This is the theorem referred to by Pippard and Baker[7] and other writers as "Castigliano's Second Theorem," but the proofs usually given are valid for pin-jointed frames only.

Examples of the use of this theorem are given in Part 3, examples 8 and 9.

SECOND THEOREM OF COMPLEMENTARY ENERGY

For a linear elastic structure S = U, so that the theorem of Least Work could as well be stated in terms of the complementary energy. This gives no practical advantage. However, for certain non-linear elastic structures complementary energy may serve where strain energy fails, and this second theorem is the equivalent of the Least Work theorem for use in non-linear systems.

The first complementary energy theorem may be simply extended to treat the case when two of the external loads, P_s and P_t, are equal and vary together. Following the same argument as before let both loads be increased to $P_s + dP_s$, and the increase in complementary energy is again $\frac{\partial S}{\partial P_s} dP_s$, on the understanding that P_s is written for P_t in the expression for S before differentiation (proposition A).

For all points other than *s* and *t* the reaction/displacement graphs will behave as indicated in Fig. 8, opposite, *s* and *t* having graphs as in Fig. 7. But note that, though $P_s = P_t$, in general $\Delta_s \neq \Delta_t$, so that a second expression for the total increment to S is $(\Delta_s + \Delta_t)\, dP_s$. Then

$$\frac{\partial S}{\partial P_s} = \Delta_s + \Delta_t. \quad . \quad . \quad (17)$$

It was shown in equation 4, Part 1, that the complementary energy of any elastic structure, allowing for self-straining, is

$$S = \sum_r \int_0^{P_r} d_r\,(R_r, P_r, \ldots Q_i, \ldots)\, dR_r + \sum_i \left\{ \int_0^{Q_i} d_i(R_i, P_r, \ldots Q_i, \ldots)\, dR_i + \int_0^{Q_i} d'_i\,(R'_i, P_r, \ldots Q_i \ldots)\, dR'_i \right\}$$

a function of the forces P_r and Q_i only. At each point *i* there is a pair of equal forces Q_i which, if the "cuts" have not yet been cemented up, are external forces. Hence if *j* is a particular one of the points *i*, by equation (17)

$$\frac{\partial S}{\partial Q_j} = D_j + D'_j, \text{ or } d_j\,(Q_j) + d'_j\,(Q_j).$$

If the forces Q_j are positive when they tend to close the gap at *j*, remembering that D represents a displacement from the initial position of the unloaded cut structure, we have, since, Q_j is the value required to close the gap at *j*

$$\frac{\partial S}{\partial Q_j} = D_j + D'_j = \lambda_j. \quad . \quad (18)$$

The quantities $\frac{\partial d_j}{\partial Q_j}$ and $\frac{\partial d'_j}{\partial Q_j}$ are both positive, being the rate of increase of displacement for increasing load, so that $\frac{\partial^2 S}{\partial Q_j^2}$ is positive. Then by proposition E, if $\lambda_j = 0$, Q_j must take such a value as will make S a minimum. Hence the first form of the theorem states that: *If the complementary energy of any initially unstressed elastic structure is expressed in terms of its n redundancies and the externally applied loads only, then each redundancy must take such a value as will make the expression a minimum.*

The extension to a more general theorem, using *n* quantities a_p instead of the redundancies, can be made in this case just as in the theorem of Least Work.

When λ_j is not zero, equation (18) gives the theorem for self-strained structures: *If the*

complementary energy of any elastic structure is expressed in terms of its n redundancies and the externally applied loads only, then its partial derivative with respect to a redundancy Q_j gives the dislocation which would occur at j in the line of action of Q_j if n cuts were made in the unloaded structure, one at the point of action of each redundancy, so as to release all the self-straining.

This definition is true for any elastic structure, but unfortunately the complementary energy cannot always be expressed in the required form (as was shown in Part 1). In the case of a pin-jointed frame the dislocations will be the initial lack of fit of the redundant members.

Note that in finding the redundant forces in the loaded structure we differentiate the expression for S for the loaded structure; but the result is the dislocation which would be produced by cuts in the *unloaded* structure, that is, the *initial* lack of fit. The internal forces are no longer the sum of forces due to external loads and self-straining considered severally.

The procedure in applying this theorem is illustrated in Part 3, examples 10 and 11.

DISCUSSION

The main object of structural analysis is to calculate the stresses or displacements of a structure when the loads or displacements at particular points are specified. For an elastic structure the principles governing the deformation and stresses are internal and external equilibrium, an empirical law relating stress to strain, and the compatibility of strains (that is, single-valued displacements); and the principles are not changed by the choice of energy as medium for the solution. The elegance of energy methods is that they enable equilibrium to be expressed in terms of displacements, compatibility in terms of forces; from a solution in terms of loads there is an energy theorem to find the displacements, and from a solution in terms of displacements a theorem to find the loads. The user, according to what is specified or required, may choose whether he desires to deal in forces or in displacements, and there is an energy theorem to express the awkward principle in his own terms. Only in very simple, statically-determinate, cases does the choice fail. Then, if the problem is of stress-determination, to use energy at all he must apply to displacements. It is rarely worthwhile.

When a structure has only a small number of redundancies the stresses are often most speedily found by working in terms of forces. But Southwell[8] has put forward an argument which may make solutions in displacements more popular in such cases. Commenting that structural problems often lead to ill-conditioned simultaneous equations, that is, equations where small variations in the constants give large variations in the required unknowns, Southwell points out that in a solution in displacements the constants are external forces. In this case if the equations are ill-conditioned the structure has not been competently designed, for small changes in the external forces will give large changes in the displacements. Conversely, a well-designed structure, solved in terms of displacements, will not give ill-conditioned equations.

Part 2 of this paper has examined the conditions under which the energy theorems are valid. The limitations on each theorem are to be found in the foregoing pages, but two general observations may be made. First, that for any theorem to be validly applied the energy must be expressed in a proper form. It is idle fallacy to build an expression for the strain energy in any terms that are convenient, to make the expression a minimum with respect to any variable at hand, and to ascribe the result to the theorem of Least Work. Second, that although for a solution in displacements it is immaterial how many displacements appear in the energy expression, for a solution in terms of loads there is no such liberty. Except for the statically-determinate supports, which must never appear explicitly, it is fair to state the energy as a function of any external loads; but internal loads, moments or stresses may only appear in calculations using Least Work or the second theorem of complementary energy, and even then the number of internal forces used must not exceed the degree of redundancy of the system.

Relation between the Theorems

Williams[6] has pointed out, in a most interesting paper, that the energy theorems are not all independent. The inter-dependence is immediately seen from the proofs above, and it is interesting that the approaches given here suggest a different grouping of the theorems from that of Williams. The proofs of this article imply three groups:

(i) Castigliano's equilibrium theorem, the theorems of virtual work and minimum total potential energy, and the first theorem of minimum strain energy;

(ii) Castigliano's theorem for linear structures, and the first theorem of complementary energy; and

(iii) the second theorem of minimum strain energy, the theorem of Least Work, and the second theorem of complementary energy.

Some writers, for example, Timoshenko and Goodier[9], Den Hartog[10], only give one from each group, no doubt because of the fundamental identity of some of the theorems.

The first group express equilibrium and are used for solutions in terms of displacements. They are comparatively free of pitfalls, for the energy expression may involve as many displacements as is convenient, and the theorems hold for both linear and non-linear structures. The minimum strain energy theorem is reserved for structures with specified displacements; but the others are applicable whether loads or displacements are given, and have small advantages over each other in particular cases.

The second group deduce displacements from an energy expression in terms of loads, the reverse procedure of Castigliano's equilibrium theorem which deduces loads from an expression in displacements. Castigliano's theorem in the second group will only contend with linear structures, but for certain non-linear structures the same service is performed by the complementary energy theorem. This will be discussed more fully later.

The third group express the compatibility of strain and displacements in terms of the loads. The second minimum strain energy theorem expresses external compatibility, and is thus the condition for finding redundant supports for linear structures under specified loads. The other theorems are concerned with internal compatibility, and by their extensions deal with self-straining also. The form of the energy expression now is critical. The possibilities of internal and external equilibrium must be exhausted first, and the energy expression may involve only that minimum number of internal forces which cannot, by equilibrium, be expressed in terms of the external loads and each other. The theorem of least work is applicable to linear structures only, but its function is extended to deal with certain non-linear structures by the second theorem of complementary energy.

Uses of Complementary Energy

It remains to discuss the position and use of complementary energy. At first sight one might expect Castigliano's theorem for linear structures and the theorem of Least Work to be superseded by the complementary energy theorems, which appear to have a wider generality, covering the linear structure as a special case. Nevertheless, the present popularity of strain energy methods is likely to remain. Strain energy is defined as work done, a familiar physical idea which the purely mathematical definition of complementary energy can never rival for simplicity. Furthermore strain energy is a partner in the group of energy forms which subscribe to the conservation principle. These physical concepts preserve in the user a "feel" for the structure which, in complex calculations, is a great aid to the correct application of the theorems.

The proper field for complementary energy is the analysis of non-linear structures, and unfortunately the theorems are not as widely applicable as one could wish. There are two sources of non-linearity in elastic structures: change of geometrical shape and non-linear characteristics of material. The complementary energy theorems, as they have been enunciated here, are valid for any elastic structure (in this paper we are not concerned with a non-elastic structure), and they are immediately applicable when the non-linearity arises solely from the second source. When there is change of geometry, however, although the theorems are valid the condition of superposition between displacements and strains is not fulfilled, and in general it is not possible to express S in a useful form. But in a composite structure with one or more non-linear components the complementary energy theorems may fairly be applied, even if the non-linearity results from change of geometry within the component, provided there is no change of geometry of the rest of the structure. It is only necessary that the characteristics of the components be known as far as they affect the rest of the structure. This procedure is demonstrated in examples 4 and 10 of Part 3.

In other cases, when the change of geometry is not too great, complementary energy may be used as an approximate method, with quite good results. (Several examples are given by Westergaard[3]).

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[8] R. V. Southwell, "Current Trends in Structural Research," published in *Engineering Structures*, Butterworths Scientific Publications, 1949.

[9] S. Timoshenko and J. N. Goodier, *Theory of Elasticity*, McGraw-Hill, 2nd edn., 1951.

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Part 1 of this article was published on page 305 of our issue for March 11; Part 3 will be published in the near future.

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REDUCING FIRE RISKS

Gypsum, either as a plaster or in the form of plasterboard, offers a high degree of fire-resistance. In the form of plasterboard it provides good thermal insulation, and for both reasons the building products of gypsum can find many useful applications in the construction of factories and other engineering establishments. The Gypsum Building Products Association, 11 Ironmonger-lane, London, E.C.2, are starting a campaign to show industry the reductions in fire-hazard that can be achieved by the use of their products. Technical information on the fire-resistant properties can be obtained from the Association, and it is hoped to produce a quarterly publication, *The Gypsum Journal*, beginning next April, which will contain general information on gypsum products.

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ALUMINIUM WORKS MODERNISATION

The Northern Aluminium Company, Limited, have announced an extensive remodelling and modernisation scheme for their Banbury works. The scheme will take place in several stages and will be completed in 1958. Much of the present equipment was installed between 1931 and 1939; among the new machines will be a hot mill capable of handling ingots over a ton in weight. The modernised plant is designed to complement the range of products made at Rogerstone, Monmouthshire.

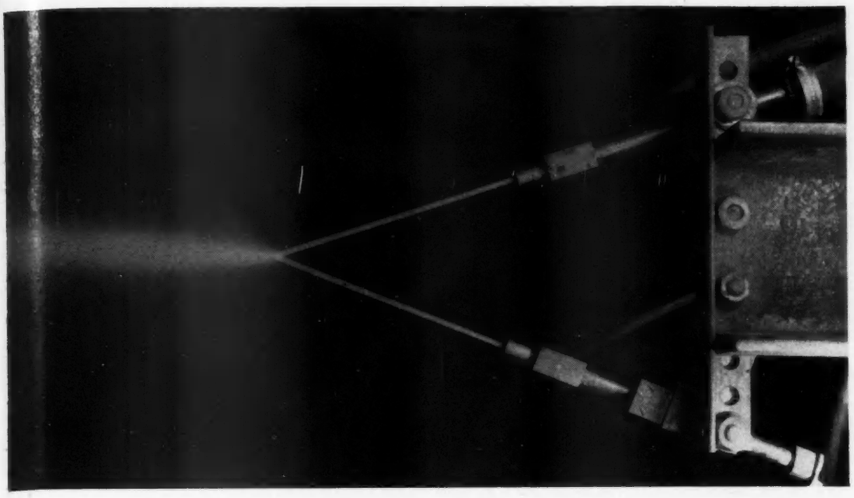

Fig. 1 The character of sprays formed by pairs of impinging jets was investigated by measurements of drop distribution.

THE PRODUCTION OF FIRE-FIGHTING SPRAYS BY IMPINGING JETS

By J. F. Fry, B.SC., A.M.I.C.E., *P. H. Thomas*, M.A., PH.D., *and P. M. T. Smart*

As part of a programme of experimental work on fire-fighting sprays an examination has been made of the sprays formed by single pairs of impinging jets. The nozzle diameters used were $\frac{1}{16}$ *in.,* $\frac{1}{8}$ *in., and* $\frac{3}{16}$ *in., and they were operated at various pressures up to* 120 *lb. per square inch, and with various angles of impingement up to* 90 *deg. Measurements have been made of the quantity distributions over the floor areas wetted by the sprays and of the droplet populations within the sprays. A reduction in the diameter of the nozzles was found not only to decrease the median drop diameter but also to increase the uniformity of both the drop-size distribution and the distribution of water falling from the spray; for a given size of nozzle the median drop diameter was lessened by increasing the velocity of approach of the jets.*

In many nozzles intended for fire-fighting, use is made of the principle of spray formation by impinging jets.[1] Pairs of jets are usually arranged so that they impinge either slightly ahead of the nozzle or radially around it, and the spray may be in the form of a cone, a flat sheet or a roughly spherical cloud. Similar sprays are used to inject fuel into combustion chambers. For experimental purposes the sprays were formed by a pair of jets equally inclined to the horizontal and impinging in a vertical plane.

EXPERIMENTAL METHODS

The spray-producing apparatus used is shown in Fig. 1, which is reproduced from a Crown copyright photograph. Three pairs of carefully-machined, conical nozzles were used, their diameters being $\frac{1}{16}$ in., $\frac{1}{8}$ in., and $\frac{3}{16}$ in., and sprays were produced with various nozzle pressures ranging from 20 lb. to 120 lb. per square inch. The quantity distribution of water falling from sprays produced by various nozzles, angles of impingement and at various pressures was measured by collecting the water for a period of 1 minute, in cans 10 in. in diameter, spaced 1 ft. apart. The tops of the cans were 4 ft. below the horizontal axis of the spray. Quantities smaller than 10 c.c. were neglected.

RESULTS OF TESTS

From the quantities collected at the various points within the wetted area, the rate of delivery at each point was calculated in gallons per square foot per minute, and from these, the quantity distributions, in the form of contoured plans of the type shown in Fig. 2, were obtained. The contour line of points receiving water at the rate of 0·01 gallon per square foot per minute was taken as the effective boundary of the wetted area; the small quantity of water outside this boundary was neglected. No consistent variation with pressure was found for the length or the width of the wetted area except below a pressure of 40 lb. per square inch, in which range an increase of pressure invariably increased the length of the wetted area. The width of the wetted area usually decreased at the same time but this was not so for all spray conditions. Since these effects were not large, values for length and width of wetted area averaged over the pressure range are shown in Figs. 3 and 4. The wetted area itself was estimated by assuming the measured length and width to be the axes of an ellipse and is given in Fig. 5. The results suggest that the average concentration of water increases with size of nozzle, i.e., rate of flow, particularly between $\frac{1}{8}$-in. and $\frac{3}{16}$-in. nozzles.

In order to obtain some measure of the uniformity of the distribution of water within the wetted area, the average concentration of water was obtained by dividing the total flow by the wetted area so that the ratio of the maximum to average concentration could then be taken as a measure of the uniformity of water distribution. This ratio was not found to vary significantly with pressure and average values are shown in Fig. 6 for the various spray conditions.

MEASUREMENT OF DROP SIZE

Samples of drops from the sprays to be examined were collected in castor oil, a method found useful by others investigating water sprays[2,3]. Two samples were collected at each of seven points in a horizontal plane 4 ft. below the point of impingement of the jets, five of these points being on the centre line of the spray. The positions of these points were chosen after observing the shape of the spray pattern on the floor and included the edges of the effective wetted area. The droplets collected in the castor oil remained stable for several minutes, allowing ample time for a permanent photographic record to be obtained directly as paper negatives, and from these the distribution of drop size was obtained by counting with a slotted gauge the drops with diameters falling into certain size groups covering the range 0·05 to 1·05 mm., at intervals of 0·10 mm.

ANALYSIS OF DROPLET POPULATION

A preliminary examination of the results

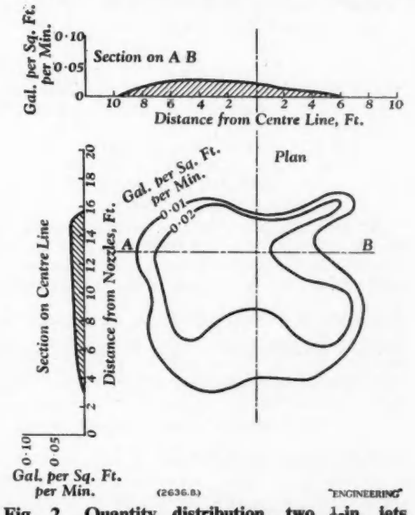

Fig. 2 Quantity distribution, two $\frac{1}{8}$-in. jets. (Pressure 20 lb. per square inch, included angle 90 deg.).

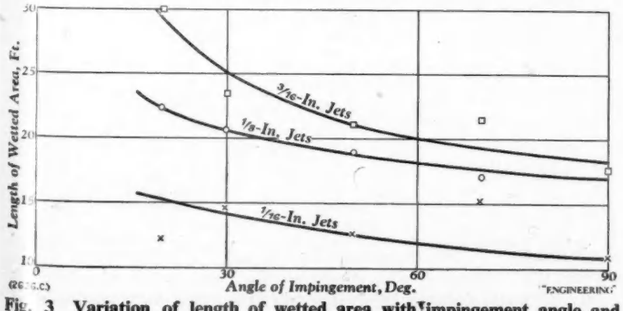

Fig. 3 Variation of length of wetted area with impingement angle and nozzle size.

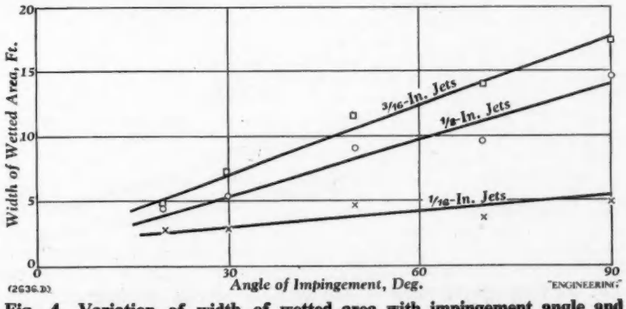

Fig. 4 Variation of width of wetted area with impingement angle and nozzle size.

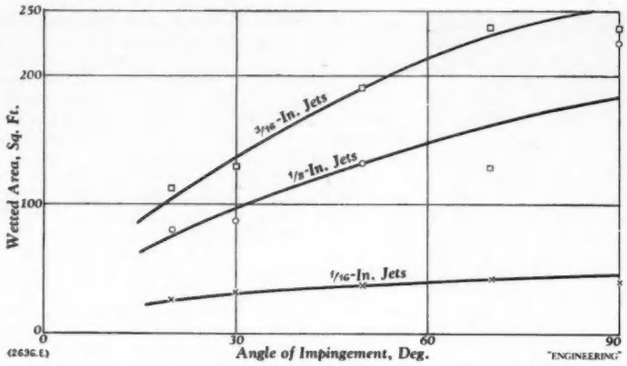

Fig. 5 Variation of wetted area with impingement angle and nozzle size.

showed that very near the nozzle, small drops only were falling to the ground, but this was mainly outside the region regarded as the effective wetted area. Similarly, beyond the effective wetted area, at the extreme range of the spray, the small quantity of water falling appeared to consist mainly of large drops. In the main body of the spray a mixture of droplet sizes appeared to be present at all points. This effect may be partly due to the fact that air is entrained in the spray and carries the smaller particles farther than they could travel by themselves in still air; it may be partly due also to some coalescence of the smaller drops, giving rise to the presence of large drops nearer to the nozzle than would be expected. In view of these observations it was considered that a reasonable overall picture of a spray could be best obtained by summing the drop counts taken at all parts of the spray pattern. In order to represent the drop size distribution of the various sprays by suitable parameters, such as specific surface or mass median diameter, use was made of the Rosin-Rammler Law[4], which has been used to represent the drop size distribution of fuel sprays[5].

A convenient form of the law is

$$R = e^{-\left(\frac{x}{\bar{x}}\right)^n}, \quad . \quad . \quad . \quad . \quad . \quad (1)$$

where R = fraction by weight of the total spray composed of drops greater in diameter than x,

$\bar{x}$ = " absolute spray constant " (equal to the value of x for which the fraction R over size is 0·368),

n = homogeneity coefficient.

An increase in n implies a greater uniformity in drop size, and an indefinitely large n implies that all the drops are the same size. The values of $\bar{x}$ and n were found graphically. If the value of $\log \frac{1}{R}$ is plotted against x on logarithmic scales a straight line of slope n is obtained, $\bar{x}$ being the value of x at which $\log \frac{1}{R} = \log e$. The mass median diameter is given by $\log \frac{1}{R} = \log 2$ and the specific surface by

$$S = \frac{6}{\bar{x}} \Gamma\left(1 - \frac{1}{n}\right) \text{ sq. cm. per cub. cm.}, \quad (2)$$

where Γ is the gamma function.

A typical logarithmic plot of x on a base of $\log \frac{1}{R}$ is given in Fig. 7, and the values of the mean median diameter n and the specific surface S for each of the spray-producing conditions examined are given in the table below.

INFLUENCE OF VELOCITY OF IMPINGEMENT

Since the essential mechanism employed in forming the sprays in these experiments was the impingement of two jets it would seem reasonable to expect that the velocity of impingement would have some effect on the particle size of the spray. The relation of drop size to approach velocity is therefore shown in Fig. 8; the approach velocity being given by $v \sin \frac{\theta}{2}$, where v is the velocity of each jet and θ is the angle included between the two jets. Although there is some scatter of the points it is nevertheless clear, as might be expected, that the particle size tends to decrease with increasing approach velocity. Within the range of the experiments there appears to be an approximately linear relation between mass median diameter and approach velocity given by:

$$x_m = 0{\cdot}775 - 0{\cdot}005\, v \sin \frac{\theta}{2}.$$

Influence of jet diameter.—Insufficient results are available to obtain a quantitative law relating particle size to jet diameter but, from the data given in the table, it may be seen that particle size has a general tendency to increase with increasing jet diameter. This effect is less marked for 90-deg. impingement than for 30-deg. impingement.

There is no evidence of any effect of pressure in the range of these experiments on the value of n, the homogeneity coefficient. Increasing the jet diameter, however, or increasing the angle of impingement from 30 deg. to 90 deg. has the effect of making the distribution of drop size less uniform.

Diameter of Jets	Angle Included by Jets	Pressure P	Homogeneity Coefficient n	Median Drop Diameter x_m	Specific Surface S
In.	Degrees	lb. per sq. in.	±σ	mm.	Sq. cm. per cub. cm.
1/8	90	20		0·68	110
		40		0·46	178
		60	2·60	0·52	158
		80	±0·11	0·39	200
		100		0·40	186
		120		0·31	231
1/8	70	20		0·62	122
		40		0·49	141
		60	3·0	0·54	134
		80	±0·15	0·46	159
		100		0·47	145
		120		0·39	173
1/8	50	20		0·31	212
		40		0·55	140
		60	3·10	0·50	141
		80	±0·18	0·55	126
		100		0·46	158
		120		0·43	160
1/8	30	20		0·65	111
		40		0·55	123
		60	3·12	0·60	119
		80	±0·15	0·58	120
		100		0·77	95
		120		0·71	109
1/4	90	20	2·37	0·76	103
		60	±0·12	0·46	172
1/4	30	20	2·75	0·80	88
		60	±0·31	0·82	91
1/16	90	20	2·50	0·78	101
		60	±0·33	0·92	83
1/16	30	20	2·0	1·30	75
		60	±0·28	1·10	75

CONCLUSIONS

By varying the angle of impingement and the nozzle diameter of a pair of impinging jets it is possible to obtain a variety of spray patterns so that the area of floor wetted by the spray may be long and narrow or short and wide. Within the range of nozzles examined the area covered increases with increasing nozzle diameter and for a given angle of impingement of the jets. It also increases with impingement angle, particularly for the larger jets. There is evidence that increasing the diameter of the nozzles decreases the uniformity of the distribution of water. Atomisation is improved (i.e. a greater specific surface is obtained) by increasing the velocity with which the jets approach each other. With a pair of 1/16-in. jets operating at pressures up to 120 lb. per square inch and at angles of impingement up to 90 deg. it is possible to obtain a range of sprays with median drop sizes varying from 0·7 to 0·3 mm. Increasing the diameter of the spray nozzles decreases the homogeneity of the sprays and increases the drop size.

ACKNOWLEDGEMENT

The work described in this paper forms part of the programme of the Joint Fire Research Organization of the Department of Scientific and Industrial Research and Fire Offices' Committee;

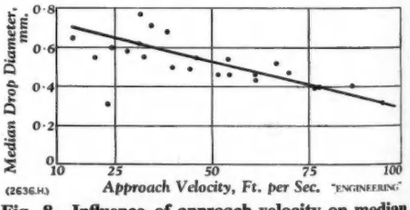

Fig. 8 Influence of approach velocity on median diameter, using two 1/16-in. impinging jets.

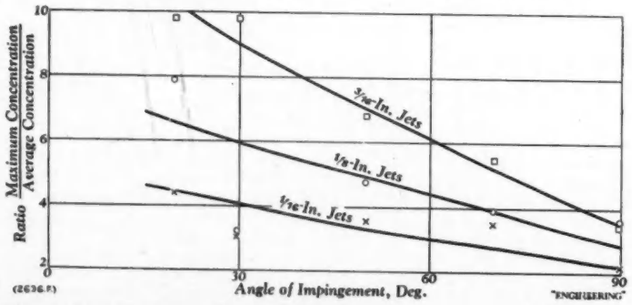

Fig. 6 Variation of ratio of maximum to average concentration with impingement angle and nozzle size.

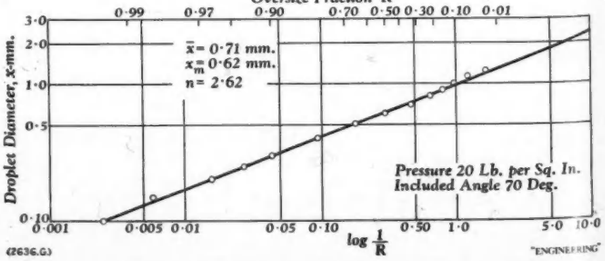

Fig. 7 Rosin-Rammler lines for sprays from two 1/16-in. impinging jets. (R = fractional weight of total spray with drop diameter exceeding x.)

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A COMPARISON OF GAS TURBINES

WEIGHT AND BULK AS FACTORS IN CHOOSING PROPELLING PLANT FOR NAVAL VESSELS

Four classes of gas turbine for naval use, each consisting of a cruising and a boosting engine, were compared in a paper delivered before members of the North-East Coast Institution of Engineers and Shipbuilders on Friday, March 11. The paper, which was entitled "A Comparison of the Total Weight and Bulk of In-Line Naval Gas Turbine Engines of Differing Degrees of Complexity," was presented by D. F. Collins, B.Sc. (Eng.), and D. W. Thomas, and their aim was to determine the most suitable gas-turbine propulsion plant for naval vessels of medium size. The authors had investigated the effects of progressively increasing complexity in naval gas turbines in terms of: weight and bulk of plant plus fuel for a given operating schedule, plant layout in a typical ship, and the size of deck openings; and in their conclusions they assessed the merits of each design with respect to these criteria. In addition to graphical interpretations of the results, the paper included flow diagrams for the various turbine schemes, and layout drawings of typical installations. A summary of the paper is published here with the permission of the Controller of H.M. Stationery Office, and acknowledgment is also made to the Chief Scientist of the Ministry of Supply. The drawings reproduced are Crown copyright.

BOOST AND CRUISE ENGINE COMBINATIONS

Each complete power plant considered consists of two engines. One, designed to be in continuous operation, would supply power up to one-third of the total output, while the other would be coupled when required to the common propeller, to supply extra power up to the maximum capacity. The purpose of using two engines to cover the complete power range is primarily to ensure that each engine can be designed to suit that part of the range over which it operates.

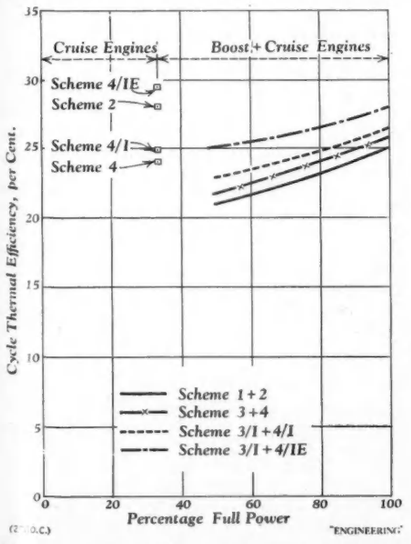

Fig. 3 A comparison of cycle thermal efficiencies in terms of total combined engine power. The double-compound schemes prove to be the more efficient.

Thus the engine providing the cruising power (a low percentage of full power) can be a complex high-efficiency engine with a low specific fuel consumption; whereas the engine supplying the additional power to bring the output to its full value may be of simpler design, since fuel economy at such powers is less important than under cruising conditions. Previous design studies, carried out at the National Gas Turbine Establishment,* have shown that, compared with

TABLE I.—*Details of the seven gas-turbine engines which in sets of two are compared in the paper*

Engine nomenclature used in the paper	Engine scheme (single compressor or double compound)	Duty and design power	Overall Pressure ratio (including intercooler pressure loss)	Maximum cycle temperature deg. K.(deg. F.)
1	1/LP	Boost 2/3 total plant power	6	1,088·7 (1,500)
2	1/LP/E	Cruise 1/3 total plant power	6	1,005 (1,350)
3	2SC/IP	Boost 2/3 total plant power	12	1,088·7 (1,500)
3/I	2SC/IP/I	Boost 2/3 total plant power	12	1,088·7 (1,500)
4	2SC/IP	Cruise 1/3 total plant power	12	1,005 (1,350)
4/I	2SC/IP/I	Cruise 1/3 total plant power	12	1,005 (1,350)
4/IE	2SC/IP/IE	Cruise 1/3 total plant power	12	1,005 (1,350)

TABLE II.—*Engines used in combination in the four power plants considered*

Boost engine	+	Cruise engine
1	+	2
3	+	4
3/I	+	4/I
3/I	+	4/IE

* "The Selection of a Marine Gas Turbine Cycle, Part II", by W. R. Thomson, W. G. Lydiard and J. A. Barnes, unpublished work at N.G.T.E.

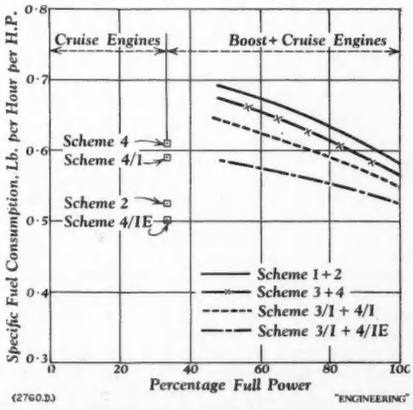

Fig. 4 Relationship between specific fuel consumption and total engine power. The advantage of the double-compound schemes is enhanced by intercooling and heat exchange.

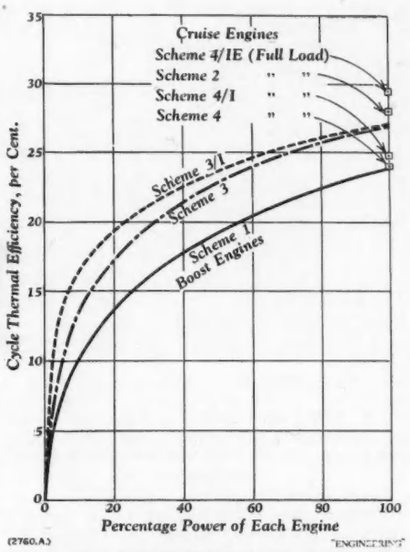

Fig. 1 Cycle thermal efficiencies of boost engines in terms of output, which is given as a percentage of full boost-engine power. Point values for cruise engines at design power are also shown.

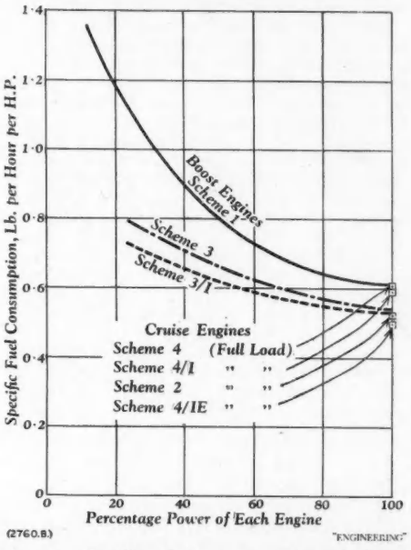

Fig. 2 Specific fuel consumption of boost engines in terms of percentage engine power with point values for cruise engines. The double-compound turbines display higher efficiency than the single-compressor version.

a single-engine arrangement of similar thermal efficiency, a two-engine plant could offer a considerable saving in bulk, although a larger number of components would of course be used.

IN-LINE ARRANGEMENT

In the present study, the engine components, with the exception of intercoolers and heat exchangers, are arranged co-axially. Such in-line arrangements reduce to a minimum the complexity of ducting and volutes. It is emphasised that only naval vessels of medium size are under consideration, and that in small coastal craft where bulk and plant weight must be kept as low as possible, the most suitable form of gas-turbine plant would probably be simpler than those discussed.

After consideration of thermal efficiency and certain other factors, two basic types of engine were selected for detailed study: a single-compressor in-line design in which the power is supplied by a separate low-pressure power turbine; and a double-compound in-line scheme

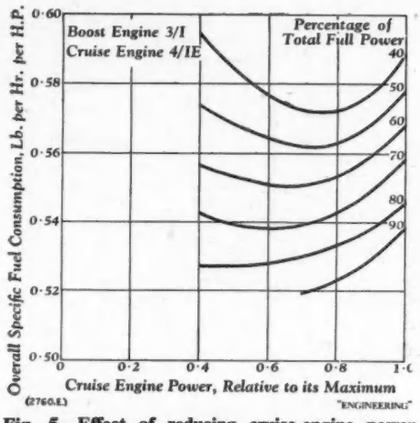

Fig. 5 Effect of reducing cruise-engine power and increasing boost-engine power for a given total output. In this way a fuel economy can be achieved.

in which power is provided by a separate intermediate turbine disposed between the high-pressure and low-pressure compressor turbines. These two arrangements are represented respectively by the symbols 1/LP and 2SC/IP. In both schemes the annular combustion chamber is placed in line with the compressors and turbines, and encloses the connecting shafts.

Table I gives the nomenclature used throughout the paper, and also lists for each scheme, the designed power, pressure ratio and maximum cycle temperature. The letters I and E indicate the addition to a basic cycle of intercooling and heat exchange respectively. Scheme 2, as a basic cycle, already incorporates heat exchange. The design pressure ratio of 6 was chosen as reasonable for the single-compressor engines, in view of the necessity to avoid surging at low powers. For the double-compound engines, the value 12 was chosen to take advantage of the increase in operating stability offered by double-compounding the compression. The values selected for design maximum cycle temperature should be attainable with solid uncooled turbine blades.

Each of the four schemes considered consists of a boost engine and a cruise engine in the combinations denoted in Table II; the code of reference is that given in Table I.

CYCLE THERMAL EFFICIENCY AND FUEL CONSUMPTION

In Figs. 1 and 2 the cycle thermal efficiency and specific fuel consumption of the boost engines are plotted against power as a percentage of their maximum output. Single point values are indicated for the cruise engines at their design power (one-third of the total plant power). Of the cruising engines, it can be seen that the double-compound engine with intercooling and heat exchange yields the highest cycle thermal efficiency and the lowest specific fuel consumption, as would be expected. The actual values are 29·5 per cent. and 0·50 lb. per hour per horse-power respectively.

Of the boost engines, the double-compound engines with and without intercooling yield much the same efficiency over the top 40 per cent. of the power range, while that of the intercooled version is appreciably higher at lower powers. The single-compressor engine yields a lower efficiency than the double-compound ones over the whole power range. The cycle efficiency of scheme 3/I at its design point is 27·1 per cent. which corresponds to a specific fuel consumption of 0·54 lb. per hour per horse-power.

In Figs. 3 and 4, cycle thermal efficiency and specific fuel consumption are plotted against total plant power for the cruising and boost engine combinations. Over the power range of 50 per cent. to 100 per cent. of the maximum, the double-compound engine combinations are all superior, from the point of view of cycle efficiency, to the single-compressor scheme; and the plant with the highest overall plant cycle efficiency is that including intercooling and heat exchange. At full power, the plant consisting of double-compound engines and employing intercooling and heat exchange (schemes 3/I + 4/IE) yields a cycle thermal efficiency of 27·9 per cent.; the corresponding specific fuel consumption is 0·525 lb. per hour per horse-power.

TABLE III.—Comparison of Plant Schemes in Terms of Engine Weight and Fuel Weight for a Typical Operating Schedule

Plant description	Weights (tons)							
	Boost engine		Cruise engine		Total engine weight	Total fuel weight	Total plant plus fuel weight	Relative total weight
Boost engine + Cruise engine	Engine	Fuel for given operation	Engine	Fuel for given operation				
3/I + 4/IE	18·2	124	22·5	353	40·7	477	518	1·00
1 + 2	14·6	145	26·8	370	41·4	515	556	1·07
3/I + 4/I	16·6	124	10·5	418	27·1	542	569	1·10
3 + 4	18·5	126	11·8	431	30·3	557	587	1·13

TABLE IV.—*Comparison of plant schemes in terms of total plant bulk and total plant plus fuel bulk for a typical operating schedule.*

Plant description	Relative total plant bulk	Relative total plant plus fuel bulk
Boost engine + Cruise engine		
3/I + 4/I	1·0	1·0
3/I + 4/IE	1·56	1·28
1 + 2	1·64	1·36
3 + 4	1·76	1·46

TABLE V.—*Comparison of plant schemes in terms of total size of deck openings.*

Plant description	Total intake area, sq. ft.	Total exhaust area, sq. ft.	Total deck opening, sq. ft.	Relative total deck opening size
Boost engine + Cruise engine				
3/I + 4/IE	35·0	34·5	69·5	1·0
3/I + 4/I	34·5	36·9	71·4	1·03
1 + 2	46·0	53·3	99·3	1·43
3 + 4	52·7	54·8	107·5	1·55

DIVISION OF POWER AND FUEL ECONOMY

Incidentally, in the division of power between the two engines of any scheme, an economy of fuel can be achieved, when power a little higher than a third of the maximum is required, by running the cruising engine below its maximum condition and exacting a slightly greater output from the boosting engine than would be necessary if the cruising engine were at its design point. The extent of the economy is shown in Fig. 5, which is constructed for the (3/I + 4/IE) combination. The reason for the economy is that the cruising engine, which employs heat exchange, has a flatter efficiency-power curve than the boosting engine; hence it is of advantage to take slightly lower powers on the cruising-engine characteristic and rather higher powers on that of the boosting engine.

WEIGHT AND BULK

Efficiency comparisons alone are not enough and it is necessary to consider in addition such factors as: the weights and bulks of power plants, the quantity of fuel required for a particular duty, and the division of operating time between cruising and full power. Figures for a typical schedule are given in Table III and apply to period of operation between refuelling; the plant schemes are listed in order of increasing total weight with relative values given in the final column. The weights of mountings; reduction gear and auxiliaries are not included.

Machinery bulk is less easily determined, since the space occupied by engine components throughout a ship is not of uniform value; moreover, such items as ladders and gangways can often be fitted in spaces not suitable for installing additional plant. For the present purpose, the bulk of a plant has been taken as the sum of volumes enclosed by envelopes surrounding adjacent components, and includes any interjacent spaces not available as sites for machinery. Table IV lists relative values so obtained, with the plants in order of increasing bulk. The final column only becomes significant when it is possible to allocate fuel space in accordance with requirements—as in a new design.

SIZE OF DECK OPENINGS

With gas-turbine machinery the necessary deck openings can for some schemes be rather large, but sizes must nevertheless be kept within acceptable limits, especially in naval vessels. Thus the area of deck openings does become a real basis of comparison. The power plants are listed in Table V in order of increasing total size of deck openings, and figures are based on mean air and gas velocities in the air intakes and exhaust stacks of 100 ft. per second and 200 ft. per second, respectively.

CONCLUSIONS

In selecting a gas-turbine installation for a particular naval duty, many factors are involved, some conflicting, and others, like maintenance and reliability, not directly amenable to analysis. However, if these considerations and the results already given are borne in mind, certain conclusions can be drawn; these may conveniently be summarised with reference to each of the four plant schemes discussed.

(3/I + 4/IE) The plant consisting of two double-compound intercooled engines in which the cruising engine employs heat exchange, yields the lowest value of plant plus fuel weight for a typical operating schedule of a medium-sized naval ship. It also needs the smallest size of deck opening.

(1 + 2) The plant consisting of two single-compressor engines, with heat exchange employed on the cruising engine, has the shortest overall length, is the second best in respect of total weight, but is among the worst for size of deck opening. It is the most difficult to install.

(3/I + 4/I) The plant consisting of two intercooled double-compound engines yields the lowest value of total bulk, is almost equal to the best for size of deck opening, but is among the worst as regards total weight.

(3 + 4) The double-compound engine plant which does not employ intercooling or heat exchange is the poorest with respect to plant plus fuel weight, total bulk, and size of deck openings.

The choice of power plant depends of course upon the relative importance attached to each of the criteria used in the comparison. An appreciable reduction of total weight, however, does appear to be very acceptable for naval applications. In view of this and the other considerations, the most attractive plant is that consisting of two double-compound intercooled engines in which heat exchange is employed on the cruising engine.

★ ★ ★

New London premises have been opened by Monks and Crane, Limited, of Birmingham, small-tool stockists, at 204-206 West End-lane, London, N.W.6. (Tel.: HAM 9624). The new premises comprise space for stocking full ranges of twist drills and other engineers' small tools, packing and despatch facilities, and offices. Mr. P. A. H. Luttrell is the London and South of England area manager. The opening of the new premises was celebrated with a reception at the Dorchester, London, on Saturday evening, March 5.

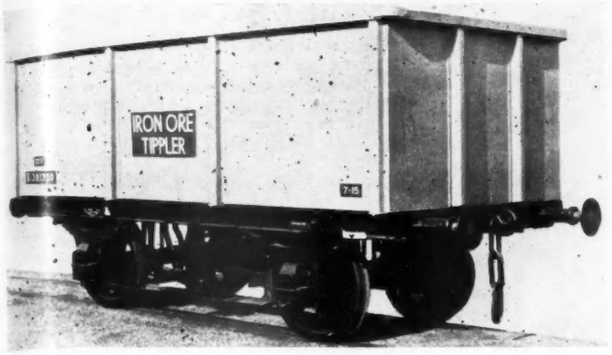

Fig. 1 Latest type of British 27-ton iron-ore tippler wagon now in common use.

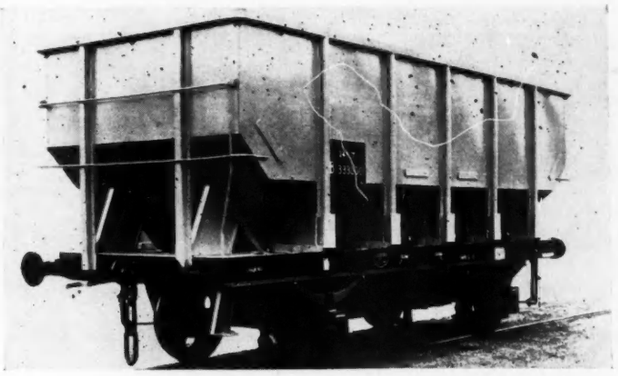

Fig. 2 New 24·5-ton coal hopper wagon for British Railways. Only a small number have so far been built.

RAILWAY WAGONS FOR IRON ORE AND OTHER BULK MATERIALS

OPTIMUM SIZES FOR BRITISH RAILWAYS

By H. R. Mills, PH.D., B.SC.(ENG.), M.I.MECH.E.*

The transport of bulk minerals by rail is greatly facilitated by the choice of the most suitable size and type of wagon. This is particularly the case with imported iron ore, because the large size of cargoes and irregularities in the arrival times of ships at the ports lead to the necessity for supplying to, and removing from, the dockside large numbers of wagons within a short period. Examination of wagons used in different countries shows that for iron ore, and for bulk minerals generally, large four-axle wagons are used almost exclusively both in Europe and America, whereas in this country, with few exceptions, the smaller two-axle wagons are used.

Fig. 1 illustrates the latest type of British 27-ton iron-ore tippler wagon which is now in common use, and Fig. 2 one of the new coal hopper wagons of which only a small number have so far been built. In Fig. 3 these two wagons, together with the new flat-bottomed coal wagon and a proposed hopper wagon for iron ore, are shown to scale. All these wagons are built to be loaded up to a gross load of 35 tons, the maximum at present on most lines in this country. For contrast, a selection of European and American iron-ore and general mineral wagons, drawn to the same scale, are shown in Fig. 4. One of the latest, built to carry ore from the new Labrador mines to the St. Lawrence, is shown in Fig. 5; it is a four-axle bogie wagon for a gross load of 112 long tons.

* Head of Plant Engineering Division, British Iron and Steel Research Association.

CRITERIA FOR AN ORE WAGON

Before deciding whether this marked difference of practice is really justified by a difference in conditions under which wagons are used on British Railways, it is necessary to be clear what are the criteria for a good railway wagon. Essentially, the best wagon is the one giving the lowest cost of transport per ton carried, which includes capital charges (interest and depreciation), cost of maintenance and repair, and operating costs (during dispatch, haulage and reception). The principal criteria for a good wagon are largely related to its suitability for dispatch and reception, which frequently occupy more time than the actual journey.

The desirable properties of an ore wagon which determine the best size are:

(1) *Maximum capacity.* The larger the wagon, the fewer units have to be filled, shunted, weighed and emptied. These operations often entail uncoupling and coupling, which it is particularly desirable to avoid when using continuous brakes.

(2) *Minimum tare weight per ton of ore carried.* The less the tare, the greater the weight of ore that can be carried in a wagon without exceeding the permitted axle loading, or in a train without exceeding the tractive power of a given locomotive, and the less the weight that has to be hauled on the return empty run.

(3) *Minimum length per ton of ore carried.* The smaller this factor, the less siding space has to be provided and the greater the weight of ore that can be carried in a given length of train, which is often limited by the length of signal blocks or intermediate sidings.

(4) *Full utilisation of dimensional and weight limits.* It is obviously desirable that, whatever the type of wagon, it should be designed up to the axle loading and overall width and height permitted. Either the axle loading or loading gauge may be the limitation on ultimate size, depending among other things on the bulk density of the material carried.

There are, of course, many other factors such as ease of filling and discharge and ease of maintenance which must be taken into account before making a final choice of the design of wagon to be adopted, but the above factors are those which determine the optimum size.

AMERICAN AND EUROPEAN PRACTICE

Direct comparison of a train composed of the best British two-axle iron-ore wagons with one composed of the best American four-axle wagons shows that the British train would be slightly heavier and nearly twice as long, and would contain nearly three times as many wagons as the American, for the same amount of ore carried. This apparent superiority of the American type of wagon, however, is mainly due to the larger loading gauge and higher axle loading permitted on American lines.

The values of loading gauge and axle loading in common use in these countries and in Western Europe are as follows:—

—	British	U.S.A.	Western Europe
Loading guage (width × height above rail)	8 ft. 6 in. × 10 ft. 8 in. or 8 ft. 9 in. × 10 ft. 0 in.	Various, but some lines are 16 ft. by 16 ft. or more.	10 ft. 4 in. × 10 ft. 5 in. for general circulation between countries.
Axle loading	17 tons 10 cwt.	23 tons 9 cwt.	19 tons 13 cwt.

For a true comparison, both types of wagon must be subjected to the same limitations of loading gauges and axle loading.

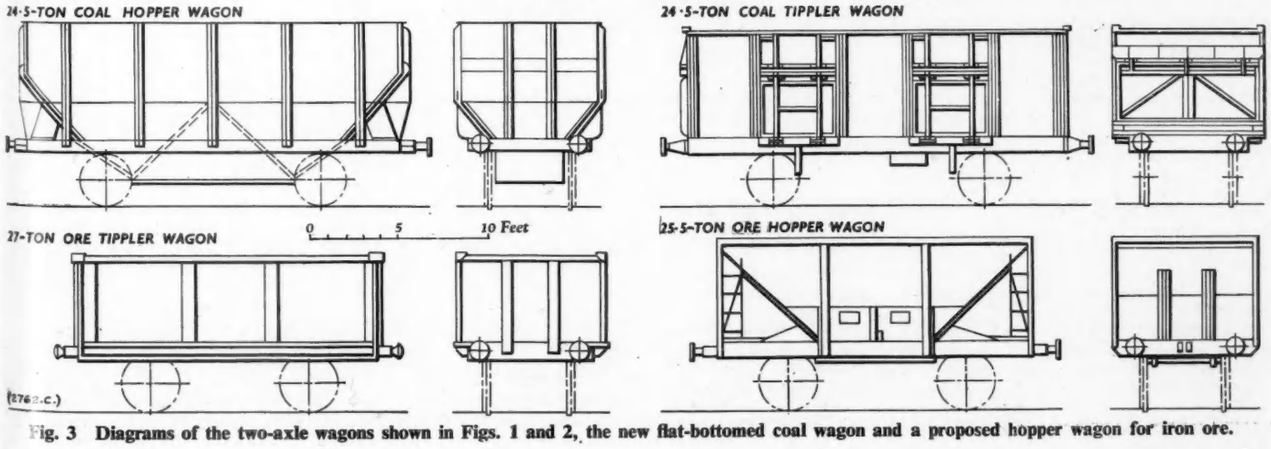

Fig. 3 Diagrams of the two-axle wagons shown in Figs. 1 and 2, the new flat-bottomed coal wagon and a proposed hopper wagon for iron ore.

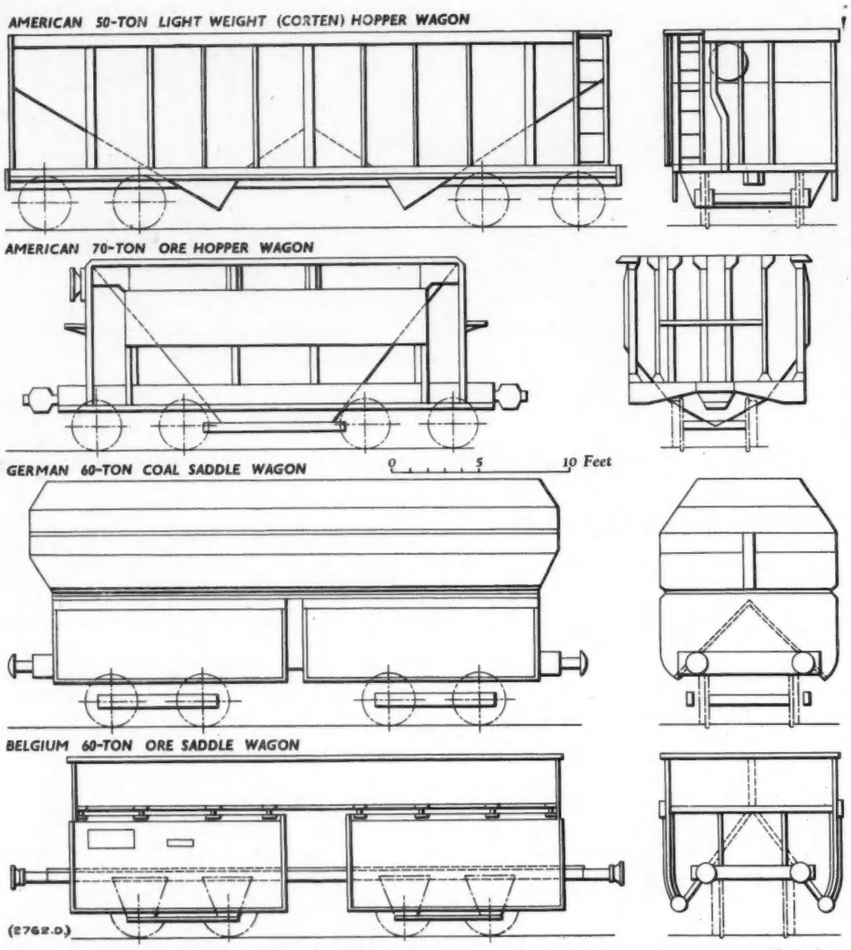
AMERICAN 50-TON LIGHT WEIGHT (CORTEN) HOPPER WAGON
AMERICAN 70-TON ORE HOPPER WAGON
GERMAN 60-TON COAL SADDLE WAGON
0 5 10 Feet
BELGIUM 60-TON ORE SADDLE WAGON
(2762.D)

Fig. 4 Selected European and American iron-ore and general mineral four-axle wagons. Figs. 3, 4 and 10 are to the same scale.

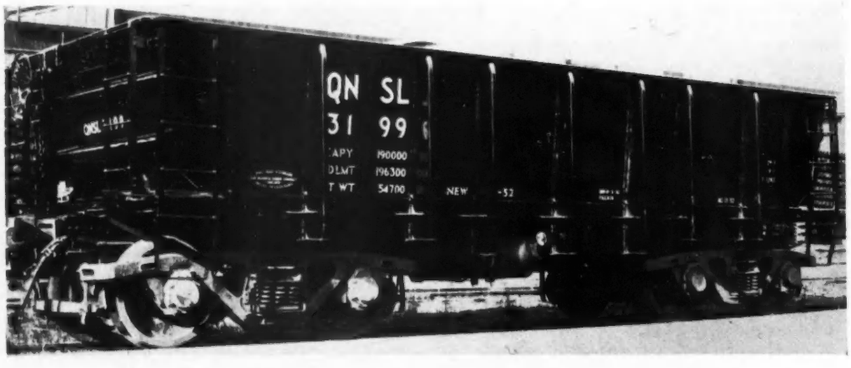

Fig. 5 Iron-ore wagon built to carry ore from the new Labrador mines to Seven Islands on the St. Lawrence. It carries a load of 87·5 tons.

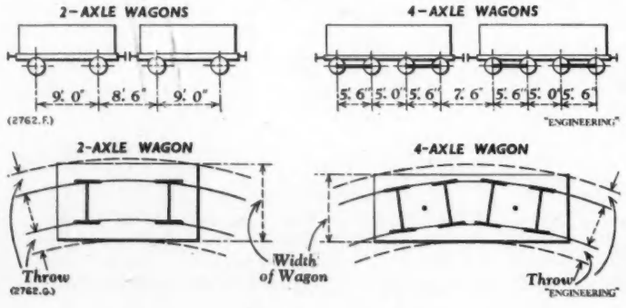

Fig. 6 Four-axle wagons carry more weight per foot of length owing to closer axle spacing.

Fig. 7 Four-axle wagons carry less volume per foot of length owing to reduced width.

CAPACITY AND WEIGHT

A requirement that a wagon should have maximum capacity appears always to favour the four-axle wagon. But when using high-capacity four-axle wagons, equipment such as tipplers and weighbridges must be made specially large to handle them, and if such equipment is provided it will handle two-axle wagons coupled in pairs equally well. Since a four-axle bogie wagon is much more expensive than a pair of two-axle wagons, the advantage of the former is not obvious unless it is also less heavy or shorter than the pair of smaller wagons.

A four-axle bogie wagon carries less weight of drawbar and buffer gear than two two-axle wagons and has two fewer ends to the body, but it carries the extra weight of the bogies and the extra structure to transmit the loads to the rail. On balance, it must probably be slightly heavier, but comparison of the load/tare ratio of existing two-axle and four-axle wagons shows a considerable range of overlapping values. The lightest examples of each class do not differ so greatly in this respect as to affect seriously the weight of a train carrying a given amount of ore.

LENGTH AND NUMBER OF AXLES

The limiting capacity of a mineral train which is, say, 1,000 ft. in length, depends fundamentally on either the cross-section through which the load must pass (the load gauge) or the load-carrying capacity of the track (which is defined by permitted axle loading and axle spacing). The first restriction is likely to apply for materials of low bulk density and the second for those of high density. A well-designed train for any given material would approach both these restrictions.

For an established railway system, the loading gauge is fixed and cannot be altered other than gradually as lines are reconstructed, so that the volume that can be carried per unit of length is limited. The capacity of the train then varies with the bulk density of the material carried, and as the bulk density is increased the axle loading can be kept within the permitted limit by spacing the axles more closely together. Ultimately, the point is reached at which closer axle spacing is not possible, and for still denser materials full use cannot be made of the load gauge and the axle loading becomes the limiting factor. The density at which this occurs depends on the loading gauge as well as on the axle loading, and is higher, the higher the permitted axle loading and the smaller the loading gauge.

So far, the way in which the train is split up into unit wagons has not been considered. Should the train be split so that each individual wagon length contains two, three, four or more axles? This question can only be answered by considering high and low density materials separately, because, as has been seen, the density determines whether the loading gauge or the permitted axle-loading is the limiting factor.

For high-density materials, the important factor is how closely the axles can be spaced. From considerations of good riding, wagons should not have too short a wheel-base, and 9 ft. (the wheel-base of the present British iron-ore wagon) is generally considered to be the minimum. Two-axle wagons cannot therefore have axles more closely spaced than one every 9 ft., while three-axle wagons or four-axle bogie wagons can have an average axle spacing of about 6 ft. This point is illustrated in Fig. 6. For materials of high enough density to make axle-loading the limitation, therefore, three-axle or four-axle wagons will increase the capacity of a train of a given length, or alternatively will give a shorter train than two-axle wagons for a given tonnage. Further increase in the number of axles to each wagon gives no advantage in this respect but adds to the engineering difficulties of distributing the wagon load between axles.

For low-density materials, the greater the number of wagons into which the train is split, the greater is the loss of capacity due to the " dead " space between wagons which is necessary to accommodate draw-gear and buffers. This consideration would also favour the use of large

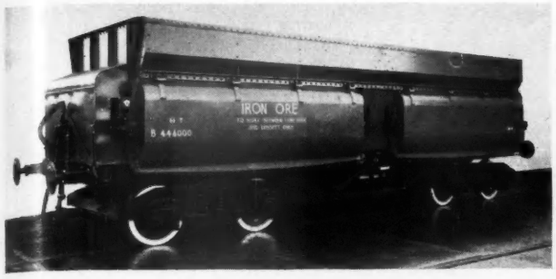

Fig. 8 Four-axle wagon for transporting imported ore from Tyne docks to Consett Iron Works.

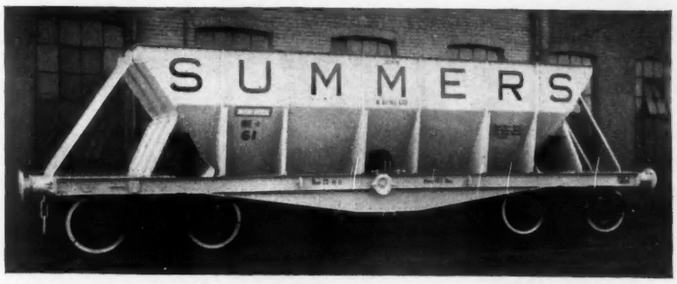

Fig. 9 Four-axle wagon for transporting imported ore from Birkenhead docks to John Summers' steelworks.

multi-axle wagons, but there is another factor which has the opposite effect and which is of particular importance on British Railways, namely, the effect of "throw" on curves. Railway lines in Great Britain were laid out largely with side clearances on curves corresponding to short rolling stock. There is, of course, considerable variation throughout the country, and new construction is being made to wider gauge and greater clearances on curves, but there are still some tunnels and other line-side obstructions on curves which limit the use of full-width wagons unless they are very short. In Fig. 7, two wagons of different length are shown fitting a curve in a tunnel, to show that increased length can only be achieved by a reduction in width. The balance of these two opposing factors cannot be decided without a quantitative analysis as referred to below.

CHOICE OF WAGON SIZE

The conditions which favour two-axle wagons are therefore:—

(*a*) Material of low bulk density.
(*b*) High permitted axle-load.
(*c*) Small loading gauge.
(*d*) Small provision for extra clearance on curves,

because under these conditions the largest body that can be built is likely to become full before the axle-loading reaches its permitted limit.

The conditions which favour four-axle (or three-axle) wagons are:—

(*a*) Material of high bulk density.
(*b*) Low permitted axle-load.
(*c*) Large loading gauge.
(*d*) Generous provision for extra clearance on curves,

because under these conditions the maximum axle-load is likely to be reached even with a body of less than maximum cross-section.

In general, these considerations apply equally to wagons designed for self-discharge (i.e., hopper or saddle wagons) or for tippling. The choice between these types depends mainly on the characteristics of the material to be carried, but is also influenced by local site conditions and the process through which the material is to be put immediately after unloading.

Compared with American and Continental railways, British Railways have a smaller loading gauge, but they also have a smaller permissible axle loading. An examination was made* of the effect of loading gauge, axle loading and restrictions to throw on curves, using the British and Western European loading gauges as examples, on the capacity of trains of a given length carrying each of the following typical materials: coal at 42 cub. ft. per ton, English iron ore at 24 cub. ft. per ton, and imported iron ore at 18 cub. ft. per ton.

This led to the following conclusions:—

(*a*) For moderate-density materials like coal, four-axle wagons are only justified in countries with a large loading gauge. With two-axle wagons more can be carried in a train of given length than with four-axle wagons, under British conditions.

(*b*) For English iron ore, four-axle or three-axle wagons give a train of somewhat greater capacity than two-axle wagons with the present British 17½-ton axle-load, but if the permitted axle-load were raised above 20 tons this advantage would disappear.

(*c*) For imported iron ore, four-axle or three-axle wagons have a considerable advantage in respect of capacity for a given train length, even with axle-loads as high as 22½ tons.

These conclusions assume that the length of a train is the limiting factor, so that the advantage of using the best type of wagon is to reduce the number of trains needed, as well as effectively to increase the capacity of sidings.

Figs. 8 and 9 show four-axle wagons now in use in this country for transporting imported ore from docks to works, and Fig. 10 shows a three-axle iron-ore wagon used for transporting Swedish ore to Narvik for export, and an indication of what a similar wagon would look like if redesigned for British conditions.

A full assessment of all the factors involved can only be made on an economic basis, taking into account the following facts:—

(*a*) The capital cost of a four-axle bogie wagon per ton carried is about twice that of a two-axle wagon. The cost of a three-axle wagon is not known, but is probably no more per ton carried than that of a two-axle wagon so long as its wheel-base can be kept short enough to avoid large end movement of the centre axle (which implies using it only for heavy materials).

(*b*) Where the length of a train is the limitation, the running costs per ton carried are reduced as its capacity is increased up to the point at which double-heading becomes necessary. The full advantage of using the best type of wagon may therefore only be felt if suitably large locomotives are available.

(*c*) Where wagons have to be handled separately at terminals, the fewer the wagons the less is the cost per ton carried. Use of large wagons increases the cost of individual units of equipment such as tipplers and weighbridges, but where large tonnages are involved the number of units required may be reduced. If an assessment of handling costs shows four-axle wagons to be worth-while, however, it would be still more worth-while using the larger equipment to handle pairs of two-axle wagons.

(*d*) The simpler two-axle wagon probably will cost less per ton carried in maintenance and repair than the four-axle bogie wagon.

(*e*) Use of the best type of wagons will minimise the cost of providing sidings for a given tonnage of material to be stored.

In the absence of all the facts needed for a full economic assessment, it is probable that the following recommendations, which are based on a technical assessment only but bearing the above points in mind, will give a sound basis for action.

RECOMMENDATIONS

(1) For coal, and for bulk materials of light or moderate density generally, two-axle wagons should be used in Great Britain.

(2) Since British Railways have now agreed that all new track and bridges will be designed for an axle loading of 22½ tons, and since considerably more home-produced iron ore than imported iron ore is transported, iron-ore wagons for general service should be of the two-axle type.

(3) Four-axle or three-axle wagons should receive attention for transporting imported iron

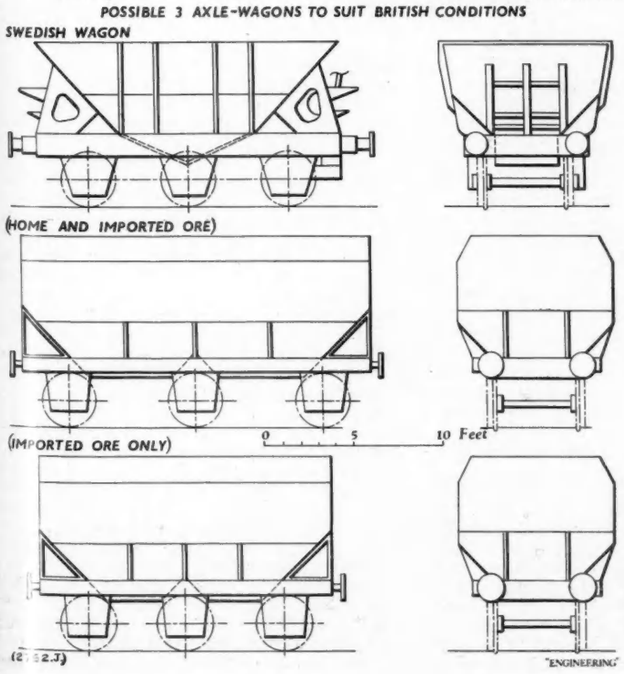

Fig. 10 Three-axle wagon for transporting Swedish ore to Narvik for export, with possible designs of similar wagons for British Railways.

* Full details are given in a Report (No. PE/D/16/54, April, 1954) issued by the British Iron and Steel Research Association.

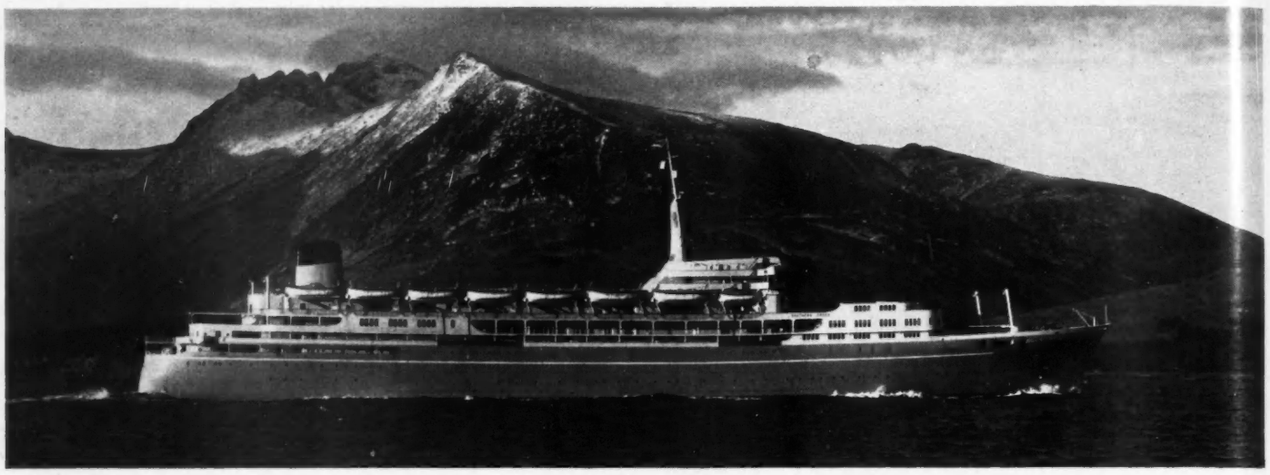

Fig. 1 Carrying no cargo, and with engines and funnel aft, the S.S. Southern Cross is designed solely for the convenience of passengers.

ore from docks to works, provided that the traffic is sufficient to justify a shuttle service and to retain the wagons for this purpose only. A four-axle bogie wagon, however, is considerably more expensive than two-axle wagons, and it is possible that a three-axle wagon, which is cheaper and gives an equally short train but involves handling more wagons, might be a suitable alternative.

(4) All wagons should be designed to make the fullest possible use of the loading gauge, and works should ensure that their own loading gauge is not more restrictive than that of British Railways, especially on sharp curves.

(5) Every effort should be made to introduce increased axle loading on all possible routes, and wagons should be designed with a view to future increase of axle loading to 22½ tons.

(6) All new track, tipplers, weighbridges and other equipment in works should be capable of handling wagons up to 45 tons gross weight. They should also be large enough to handle the new 12-ft. wheel-base coal wagons, which have a length over buffers of 24 ft. 6 in. and a height of 10 ft. 8 in. (for hopper wagons) or 9 ft. 11 in. (for tippler wagons).

ACKNOWLEDGMENTS

The author wishes to thank Sir Charles Goodeve, the Director of the British Iron and Steel Research Association, for his continued interest and encouragement during the preparation of this paper, and to acknowledge the advice and assistance of Mr. M. F. Barnard and Mr. H. Knight of the British Iron and Steel Federation during the course of the work and the help of Mr. J. G. Lee and Miss J. M. Hales in the compiling of data and the calculations involved.

(*Editorial comment in Weekly Survey.*)

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HIGH-TEMPERATURE INSULATING TAPE

An insulation tape, capable of being used in an operational temperature range of from − 50 deg. C. to + 250 deg. C., and also of withstanding a maximum of 300 deg. C. intermittently, has been produced by the Dunlop Rubber Company, Limited, St. James's House, St. James's-street, London, S.W.1.

The tape is made of silicone-rubber-spread glass cloth which is produced by coating a glass fabric with silicone rubber; the latter retains its properties at temperatures far above those which cause other rubbers to decompose. It will allow manufacturers of electric motors and similar equipment to design machines capable of working under more arduous conditions than is now possible. It will also enable the machines to take greater loading or to effect an equivalent power output with a reduction in machine size.

THE SHAW SAVILL LINER "SOUTHERN CROSS"

Accommodation arranged wholly for passengers and crew with no provision for cargo, and propelling machinery placed aft, make the Shaw Savill Line's new passenger liner an exceptional vessel. The S.S. Southern Cross, which was launched at Belfast on August 17, 1954, by Her Majesty Queen Elizabeth II, has now been completed by her builders, Harland and Wolff, Limited, Queen's Island, Belfast. She has carried out successful sea trials and has been handed over to the owners. She will make four round-the-world voyages each year from Southampton, either west about or east about as required. When westbound the outward journey will be via the Panama Canal, calling at Trinidad, Curacao, Panama Canal, Tahiti and Fiji to Wellington; the homeward journey from Wellington will be via Sydney, Melbourne, Fremantle, Cape Town and Las Palmas. When eastbound she will call at the same ports in the reverse order.

A general view of the Southern Cross is shown in Fig. 1. She has a curved rounded stem, cruiser stern, streamlined rounded top-funnel placed aft, and well rounded and streamlined bridge erections amidships, surmounted by a built steel mast in which the galley exhaust, etc., are incorporated. There are four complete steel decks, as shown in the elevation in Fig. 2: Promenade, Main, Saloon, and "A" decks; there are also Lower and "B" decks forward and aft of machinery spaces, and Lounge, Sun, Sports decks and Lower Bridge, Captain's Bridge and navigating bridge. The hull is divided into ten watertight compartments by nine bulkheads, all extending to the Saloon Deck. There is also a continuous double bottom for oil fuel and water ballast and deep tanks for fresh water. The forward and after peaks are arranged for fresh water or water ballast. Deep oil-fuel tanks are situated across the vessel forward of the machinery spaces.

The gross registered tonnage of the Southern Cross is 20,000 tons. Her principal dimensions are: length overall, 604 ft.; length between perpendiculars, 560 ft.; breadth moulded, 78 ft.; depth moulded, 45 ft. 3 in.; draft 24 ft. 9 in.

REASONS FOR UNCONVENTIONAL DESIGN

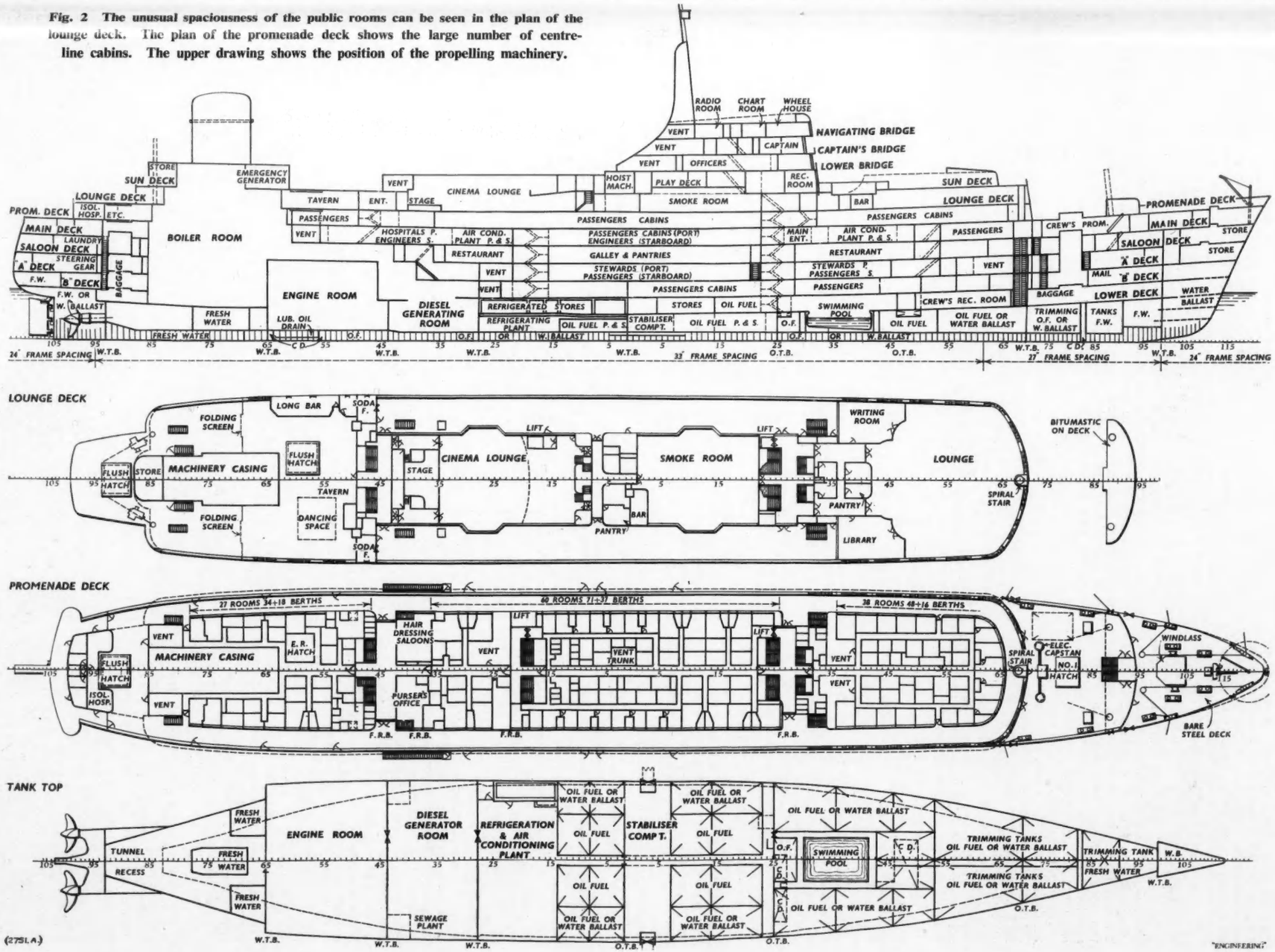
The reasons that determined the unusual design of the Southern Cross were basically economic. The Shaw Savill Line have always had both passenger and cargo obligations in the Australian and New Zealand trades, and these obligations have previously been discharged by cargo liners and combined passenger and cargo liners. Immediately after the war, during which Shaw Savill had lost a number of vessels due to enemy action, the cargo fleet was first replaced, and passenger ships were reconditioned as they were released from requisition. Shaw Savill hoped in this way to have a clear picture of the pattern of post-war traffic before building new passenger liners.

During the years after 1945 it became evident that it was often unsatisfactory to attempt to carry large cargoes and a given number of passengers in the same vessel. Changing conditions in the loading and discharge of cargo led to longer periods in ports abroad with crews on Articles, most of whom were engaged to attend to the needs of passengers, while it was invariably the cargo which was responsible for the delays and longer voyage. The difficulty of ensuring the orderly presenting of cargo to the ship's side was constantly posing this problem: should they keep to the scheduled date for which the pasengers had booked and sail with large cargo spaces unfilled, or delay dispatch to load the ship to an economic capacity ? It was generally the passenger interest that prevailed in this tug-of-war, but the result was costly and extravagant.

These were the main factors that influenced the Shaw Savill Line in their decision to build a purely passenger ship carrying no cargo whatsoever, which could make four round voyages a year to New Zealand, Australia and South Africa instead of less than three voyages possible in the same time with a passenger and cargo vessel. This decision taken, it soon became apparent that it was not only possible but highly desirable to depart from the conventional in the internal design of the ship. The absence of cargo hatches in the several passenger decks made the layout of both public rooms and cabins much easier, but still there remained the obstructions of engine room casings and funnel uptakes which normally take up so much space amidships —the best part of the ship—and handicap so severely the designing of public room and passenger accommodation.

No problems of trim could arise from the weight or absence of cargo in different hatches, as no cargo would be carried. Trim itself would be affected only by the distribution of fuel and fresh water, before and after consumption. There appeared to be no insuperable difficulty in removing the propelling machinery away from that position at the centre of the ship which is so valuable for other purposes. The whole of the engine-room machinery, boiler room and electrical generating machinery has therefore been sited as far aft as the hull would permit. In order to obviate any complications arising from the filling with salt water of the fuel-oil tanks as

Fig. 2 The unusual spaciousness of the public rooms can be seen in the plan of the lounge deck. The plan of the promenade deck shows the large number of centre-line cabins. The upper drawing shows the position of the propelling machinery.



they emptied, a triple-effect distilling plant has been installed which not only produces an adequate supply of fresh water for all passenger requirements but sufficient reserve to fill such oil fuel tanks as may be necessary to keep the vessel efficient, safe and comfortable in a seaway.

The clearance from the middle section of all hatches and other obstructions made it easier to plan the public rooms and accommodation. It also involved the introduction of a large proportion of centre-line cabins if the increased space available were to be economically used. These cabins needed air-conditioning, and plant was installed to deal with this requirement in addition to air conditioning for the public rooms and other passenger accommodation.

The steps taken were in logical sequence once the decision to design a liner with no provision for cargo had been taken: installing the machinery aft allows the public rooms to occupy the best part of the ship amidships; problems of trim are overcome by providing appropriate water-distilling plant, and air conditioning of the centre-line cabins and public rooms is achieved by plant of suitable capacity.

MACHINERY LAYOUT

Placing the machinery aft has favoured a convenient, if slightly unorthodox, layout. The position of the propelling machinery in the ship can be seen in Fig. 2, and the general layout of the machinery in Fig. 3. The boilers are astern of the turbines on a raised platform, as far aft as the narrowing hull permits, with two of the boilers abreast and forward of the third boiler. The space aft of the boiler room is used as a baggage hold. The turbines are arranged and seated in the normal manner, with the auxiliary gear grouped forward in the space between the turbines and the bulkhead between the engine room and generator room. The generators are spaced athwartships across the beam of the vessel with the electric generator end forward and directly under the switchboard. The machinery is arranged in three watertight compartments: boiler room, engine room, and generator room.

The propelling machinery, constructed by the builders, consists of a two-shaft arrangement of compound, condensing, double-reduction geared steam turbines developing 20,000 shaft horse-power at 120 r.p.m. of the propeller, sufficient to maintain the vessel at a speed of 20 knots. This power is obtained between the limits of: steam pressure at H.P. turbine inlet 465 lb. per square inch gauge, 790 deg. F. steam temperature, and a vacuum of 28½ in. (sea temperature 75 deg. F., barometer 30 in.). The L.P. turbine exhaust end is designed for 29 in. vacuum at 16,000 shaft horse-power. The turbines have been designed so that the steam consumption curve remains as flat as possible between 12,000 and 18,000 shaft horse-power. The astern turbines can develop 12,000 shaft horse-power—60 per cent. of the maximum continuous total ahead power. The H.P. ahead turbines are of impulse-reaction design and the L.P. ahead turbines of all-reaction design. For astern propulsion an impulse type H.P. astern turbine is carried on an integral extension of each H.P. ahead turbine rotor, and an impulse type L.P. astern turbine is incorporated in each L.P. ahead turbine casing. The L.P. turbines exhaust into under-slung condensers of the Weir regenerative type. G. & J. Weir, Limited., also designed the closed feed system with regenerative feed heating, the two steam turbo-feed pumps, etc.

The turbine casings are of cast construction, and those parts of the casings liable to the action of superheated system—H.P. ahead and astern turbines and L.P. astern nozzle boxes—are of cast steel. The turbine nozzles are uncontrolled up to 14,000 total shaft horse-power, and above that are controlled and grouped to give the greatest possible elasticity in operation. The turbine rotors are of forged steel, and are provided with ring water-throwers located between glands and bearings to prevent condensed steam from entering the lubricating oil system. Electrostatic collector brushes are fitted on the rotors. All reaction blading is of stainless iron, with mild-steel packing sections, stainless-iron shrouding and Lowmoor-iron side locking strips; the blades are built in sectors. The impulse blades are stainless-iron combined blades. Turbine bearings consist of removable cylindrical gunmetal bushes; all bearings are under forced lubrication and illuminated glass oil sights are provided on the outlet from each bearing.

An Aspinall governor is fitted to each L.P. turbine. Emergency connections are provided which enable these conditions to be met: H.P. turbine cut out, L.P. turbine used alone; L.P. turbine cut out, H.P. turbine used alone. Direct connection is provided so that one astern turbine can work if the other is disabled. Flexible couplings of the small-tooth type connect each turbine to its corresponding pinion shaft.

GEARING AND LUBRICATION

The power developed by the turbines is transmitted to the propeller shafts by double-reduction, articulated gearing. The gears were cut by the builders; they are double-helical type and of $\frac{7}{12}$ in. pitch all-addendum tooth form for the primary gears, and $\frac{7}{10}$ in. pitch deep-form standard involute for the secondary gears. The gearwheels and pinions are enclosed in fabricated steel gearcases which are rigidly attached to the seating in the ship. The first reduction gears are in separate gearboxes forward of the main gearing.

The turbines and their associated gearing are lubricated by a forced lubricating oil system of the pressure and head tank type, comprising double-bottom drain tanks, suction strainers, oil pumps, discharge filters, coolers and elevated supply tanks. There are three electrically-driven pumps of Drysdale and Company's Vertoil type, two working and one stand-by, each having a capacity of 25,000 gallons of oil per hour against a pressure of 70 lb. per square inch plus a suction lift of 10 ft. The control of the motors is such that any pump can be worked continuously against a reduced pressure head or at any output down to 50 tons per hour. The pumps discharge the oil through Auto-Klean oil discharge strainers and Serck oil coolers to the two gravity head tanks, each of which is of 1,250 gallons capacity. Five electrically-driven Titan oil purifiers are fitted, each capable of dealing with 300 gallons of oil per hour.

The turbines are situated immediately above the condensers, which are of G. and J. Weir's regenerative type. Each condenser has a cooling surface of 8,000 sq. ft. and can maintain a vacuum of 28½ in. with sea water 75 deg. F. (barometer 30 in.) when the turbines are developing 20,000 shaft horse-power. The cooling surface consists of Yorcalbro aluminium-brass tubes ¾ in. external diameter, 18 s.w.g. thick. There are four main circulating pumps, two for each condenser, of Drysdale and Company's DXL upright type. Each pump can deal with 7,000 gallons of water per minute against an inclusive head of 22 ft.

STEAM-RAISING PLANT

Steam for the turbines is supplied by three Yarrow water-tube boilers. The position of the boilers is shown in Figs. 2 and 3; they are arranged for oil-fuel burning, in open stokehold, with balanced draught. They are designed for a pressure of 550 lb. per square inch at the steam drum, with an aggregate maximum continuous evaporation of 180,000 lb. of steam per hour, and a controlled superheat temperature of 800 deg. F. The superheaters are of Melesco design. The aggregate generating surface of the boilers is 23,100 sq. ft., and of the superheaters 4,710 sq. ft.

The boilers burn oil fuel under a balanced system of forced and induced draught. Each boiler has an electrically-driven forced-draught fan which can deliver 22,000 cub. ft. of air per minute against a pressure of 7·68 in. of water; the driving motors are of 55 brake horse-power at 1,245 r.p.m. and their speed can be adjusted from 1,345 to 325 r.p.m. Each boiler has also an electrically-driven induced-draught fan which can deliver 30,600 cub. ft. of gas per minute with a discharge pressure of 7·53 in. of water. The speed of the motors driving the fan can be adjusted from 1,025 to 180 r.p.m. and the motors are of 180 brake horse-power at 950 r.p.m. The fans were supplied by James Howden and Company, Limited, and their positions are shown in Fig. 3. An economiser designed and manufactured by Senior Economisers, Limited, is fitted to each boiler and is located in the combustion gas outlet from the boiler. The primary section is made of steel tubes protected by cast-iron finned sleeves, and the heating surface is 4,224 sq. ft.; the secondary section is made from plain solid-drawn steel tubes without gills, and has a heating surface of 1,966 sq. ft. The economisers are designed for a water inlet temperature of 240 deg. F. and an outlet temperature of 347 deg. F. Each boiler has a Weldex bled-steam air pre-heater designed and made by Wellington Tube Works, Limited (pre-heaters of this type were described in ENGINEERING, vol. 176, page 417, 1953). The pre-heaters each raise 69,900 lb. of air per hour from 80 to 270 deg. F. when supplied with steam bled from the turbines at 50 lb. per square inch gauge and 420 deg. F.

FUEL FEED

The oil fuel is contained in tanks, which are shown in Fig. 2. There are two settling tanks of respectively 157 and 172 tons capacity, and two service tanks, each of 33 tons capacity. There are two Drysdale Vertoil pumps for oil fuel transfer, each pump being capable of delivering 80 tons of fuel per hour when pumping against a head of 100 ft. Oil is delivered to the boiler burners—of which there are four to each boiler—by units consisting of a fuel pressure pump, a heater and a discharge filter. Each boiler has two units, either of which has a normal capacity of 13,000 lb. per hour, with provision for 10 per cent. overload. Either unit can do the whole work when the propelling machinery is developing the normal designed power of 20,000 shaft horse-power. Each oil-fuel pressure pump can deliver about 5½ tons of fuel per hour against 300 lb. per square inch. The oil burning installation was supplied by the Wallsend Slipway and Engineering Company, Limited.

CLOSED FEED SYSTEM

The closed-feed system designed and made by G. and J. Weir, Limited, incorporates two main feed pumps, one working and one standby. Each unit consists of a steam turbine driving a two-stage centrifugal pump through a common shaft, the combination being mounted on a cast-iron baseplate of rigid construction. The pump can deliver, as a normal output, 180,000 lb. of feed water per hour at a temperature of 133 deg. F. from a suction pressure of 15 lb. per square inch gauge against a discharge pressure of 770 lb. per square inch gauge. The maximum output is about 30 per cent. above normal. The pumps are driven by impulse-type turbines having one pressure and three velocity stages, and have a speed of 5,350 r.p.m. when operating at normal loads. There is one assistant boiler feed pump, which can deliver 22,000 lb. per hour of feed water to the main boilers when operating against a boiler steam-drum pressure of 560 lb. per square inch gauge and supplied with de-superheated steam at 500 lb. per square inch and 475 deg. F.

There are three condensate water extraction pumps of the Weir " Lo-hed " type, two working and one standby. Each pump can deliver 117,000 lb. of water per hour as a maximum load when drawing from a condenser vacuum of 28½ in., suction temperature 92 deg. F., head over pump suction 30 in., and discharging against a pressure of 31·5 lb. per sq. in. gauge. The normal load of each pump is 90,000 lb. per hour, and they are driven by motors of 18 brake horse-power with a speed range of 1,500 to 1,650 r.p.m. The position of the extraction pumps and the feed pumps can be seen in Fig. 3.

The condensate is delivered by the extraction pumps to Maxivac three-stage air ejectors. The ejectors are supplied with steam at 500 lb. per

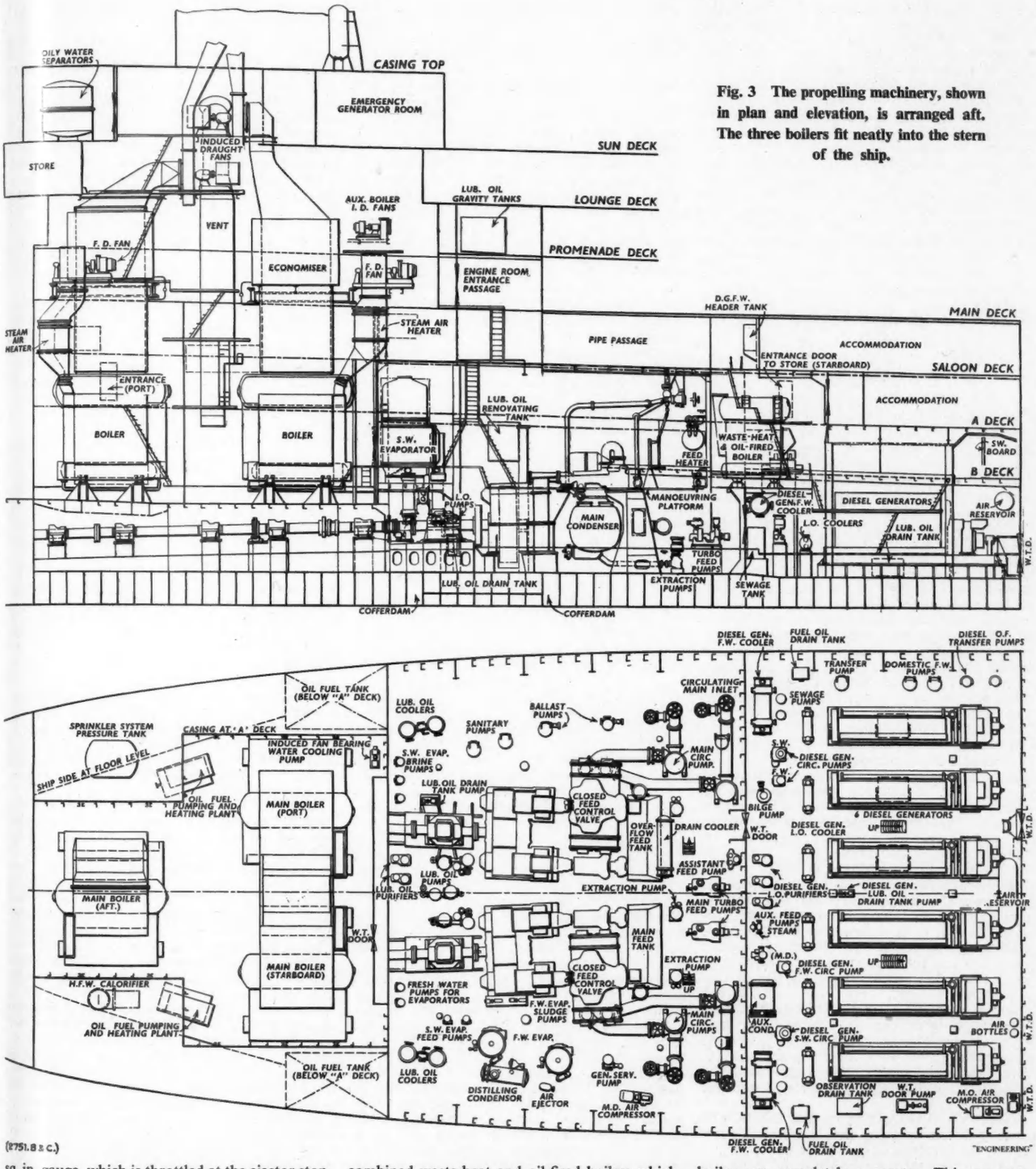


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Fig. 3 The propelling machinery, shown in plan and elevation, is arranged aft. The three boilers fit neatly into the stern of the ship.

sq. in. gauge, which is throttled at the ejector stop valve to 400 lb. per square inch for normal use. There are two sets of air ejectors, each consuming 500 lb. of steam per hour. From the air ejectors the condensate passes to the two combined gland and ejector condensers; each has a total surface of 94 sq. ft. At the discharge side of these condensers the two extraction lines combine and the feed then passes through the drain cooler to the main feed pumps. The drain cooler has a surface of 400 sq. ft., and can raise the temperature of 180,000 lb. of feed water per hour from 104·5 to 133 deg. F. The cooling surface consists of Yorcalbro aluminium-brass tubes ¾ in. external diameter, 18 s.w.g. thick.

The two auxiliary boilers are Foster Wheeler combined waste-heat and oil-fired boilers which utilise the exhaust from the Diesel generators. Each boiler is designed for 80 lb. per square inch (gauge) pressure, saturated, with an output of 1,550 lb. normal and 2,900 lb. maximum per hour from waste heat and 10,000 lb. per hour when oil-fired. Each boiler consists of a small oil-fired unit incorporating steam and water drums, a water-cooled furnace and a bank of generating tubes. On the side of the drum remote from the furnace is fitted the waste-heat section, made up of extended-surface tubes expanded into the drums in the normal way. Between the two sections a strong steel division wall is fitted so that the exhaust gases from the Diesel generators and the oil-fuel side of the boiler are completely separate. This arrangement thus incorporates a waste-heat boiler in association with Diesel engines and an oil-fired unit to supply such additional steam as may be required. The oil-fired unit operates with forced and induced draught fans with a separate system for each of the two boilers.

PROVISION OF FRESH WATER

Allocation of hull space for fresh water tanks has been reduced to a minimum, and in the normal routine all fresh water consumed on board for all purposes will be made on board. Owing to the concentration of machinery weight aft, special attention has to be paid to ballasting; all oil tanks as they become empty need to be

filled immediately to maintain the trim of the ship. To avoid the contamination of the boiler oil by sea water and its consequent ill-effect on boiler refractories, all ballasting is with fresh water made by the ship's evaporating plant. To cover the extensive duty of providing fresh water for domestic use, boiler feed and ballasting, five evaporators of Weir make are installed. Three of these are sea-water evaporators and are arranged to operate as either single or triple-effect units; when operating in triple effect they can maintain an output of 300 tons of distilled water per 24 hours from sea water. For boiler feed double-distilled water only is used, this service being given by the two fresh-water evaporators using single-distilled water from the triple-effect evaporators as feed water. These two evaporators each have a capacity of 35 tons of distilled water per 24 hours from sea water. A distilling condenser is provided for making fresh water under harbour conditions, and can work in connection with any one of the sea-water evaporators.

SUPPLY OF ELECTRICITY

The auxiliary machinery is electrically driven with the exception of the air ejectors, main and assistant boiler feed pumps and one of the auxiliary boiler feed pumps, which are steam driven. Electricity is supplied by six 220-volt direct-current generators made by W. H. Allen, Sons and Company, Limited; they are each continuously rated at 600 kW at 400 r.p.m. and have a one-hour rating of 733 kW. They are driven by Mirrlees, Bickerton and Day K8 eight-cylinder naturally-aspirated Diesel engines each with a continuous rating of 878 brake horse-power. Two self-priming electrically driven fresh-water pumps supply the engines with cooling water on a closed-circuit system incorporating tubular heat exchangers. Each heat exchanger is capable of cooling four engines simultaneously; sea water circulation is by two self-priming motor driven pumps Each engine is protected by a thermostatic alarm in the fresh water circuit and a pressure-stat in its oil circuit. An electric flow alarm and visual indicator is fitted in the fresh water main and a pressure-stat in the sea water main.

The position of the generating room can be seen in Figs. 2 and 3. The generators are level compound wound and arranged for parallel running. Both the bearings and magnet frames are split about the horizontal centre-line to facilitate erection and dismantling. The armature is of rigid construction and has a solid coupling for bolting direct to the engine flywheel. Each engine and generator are mounted as a unit on a continuuus fabricated steel base-plate. Output from generator is fed through a triple pole circuit breaker mounted on the main switchboard to the main busbars. The switch-gear on the main board was supplied by Whipp and Bourne, Limited. From the main busbars power is distributed through auxiliary switch-boards and masterboards to supply engine and boiler room auxiliaries, deck machinery, steering and stabilising gear, electric lighting and heating, etc. There are about 260 electric motors throughout the ship varying in horse-power from ¼ to 250.

There is an emergency generator of 200-kW capacity driven by a Harland and Wolff Diesel engine; the emergency generator room is just forward of the funnel on the sun deck, as shown in Fig. 2. There is also an emergency 220-volt battery which is automatically connected to the emergency busbars to maintain services essential to the safety of the ship if the main generators fail. The emergency generator can supply a limited amount of lighting, heating, cooking, and selected engine and boiler room auxiliaries during week-end periods in port when the main generators are shut down.

REFRIGERATION AND AIR-CONDITIONING

The main refrigerating machinery was supplied by J. & E. Hall, Limited; it comprises ten eight-cylinder compressors with ancillary equipment and is arranged to form six machine units. Two of these units are single compressors on their own baseplate with driving motors of 125 brake horse-power, while four are double units with a compressor coupled to each end of a 250 brake horse-power motor, both being mounted on a combined baseplate with the motor. The duty of this plant is to maintain insulated provision rooms, totalling approximately 23,500 cub. ft. capacity, at temperatures varying between 15 deg. F. to 45 deg. F.; to cool ten insulated cupboards in way of galleys; cool drinking water; make ice; circulate brine to the milk machine; also to provide refrigeration for extensive air-conditioning. A separate 4-h.p. automatic plant is fitted to maintain the Quick-Freeze provision room at −5 deg. F.

The air-conditioning and ventilating plant was installed by Thermotank, Limited, and works in conjunction with the refrigerating machinery. A large portion of the ship is fully air-conditioned, and the remainder is ventilated by air at atmospheric temperature. The plant also works on the reverse heat cycle for heating the vessel in cool weather, and can maintain a temperature of 70 deg. F. when the outside temperature is 30 deg. F. The dining saloons, cinema and concert hall, hairdressing saloons, isolation and general hospitals, passengers accommodation on the promenade, main, saloon, A and B decks, crews accommodation on the saloon deck aft, A and B decks, and recreation room on the lower deck are fully air-conditioned. When cooling is required a proportion of the air from the dining saloon, cinema and concert hall, hairdressing saloons and crews accommodation is recirculated through the units, but a constant supply of fresh filtered air equal to 15 cub. ft. per minute per occupant is introduced into the system. In the case of the passengers accommodation and hospitals, fresh filtered air only is supplied. The air is distributed by air distributors, drum-type louvres and Punkah louvres.

STABILISING AND STEERING

Both the steering gear and the stabiliser were supplied by Brown Brothers and Company, Limited. The stabilising system consists of two hydrofoils, one projecting from each side of the ship, which are controlled electro-hydraulically. As the ship rolls the hydrofoils produce a righting moment which counteracts the rolling movement. The system was described in detail in ENGINEERING, vol. 170, page 577, 1950. The steering gear is of the four-cylinder Rapson slide type having two power units, each consisting of an electric motor driving a V.S.G. variable delivery pump; each power unit is capable of full duty, the other being a standby which can be immediately brought into operation for use in entering or leaving harbour or in confined areas. The steering gear is arranged so that five combinations of hydraulic cylinders can be used—all four, two port, two starboard, two forward or two aft; the necessary change-over valves, which are all housed in one chest, are arranged for this purpose. It is telemotor controlled from the navigating position and mechanically from a pedestal fitted aft above the gear; there is also a local mechanical control on the gear. It is fitted with a Sperry Automatic Helmsman coupled to the telemotor control gear as an alternative means of steering. This is quite independent of the steering telemotor, which is bypassed when the ship is being steered by the automatic helmsman.

NAVIGATION AND WIRELESS

The gyro compass, which was made by the Sperry Gyroscope Company, Limited, is of the latest type with electronic follow-up system. The compass operates the course recorder and the gyropilot, and five repeater compasses. One is an enlarged scale repeater compass mounted on the bridge unit of the gyropilot for the helmsman; two bearing repeater compasses are mounted, one in each bridge wing, for the observation of true bearings; another repeater is included in the wireless D/F room to enable D/F bearings to be converted to true; the fifth repeater compass is installed on its own stand on the after docking bridge.

Radio communication equipment and electronic aids to navigation have been fitted by the Marconi International Marine Communication Company, Limited. Radiolocator IV radar, a Lodestone direction-finder and a Visagraph echometer are installed to aid navigation in all weather conditions. The Radiolocator IV provides a watch on all above-water objects within a range of at least forty miles from the vessel, while the Visagraph plots a contour graph of the sea-bed or gives instantaneous spot readings of the depth of water beneath the ship's keel. The Lodestone long-range radio direction-finder has gyro-compass stabilisation, so that radio bearings on coastal radio-beacons or on the transmissions of other stations can be read direct from the dial without calculations.

The Worldspan wireless transmitter, in conjunction with the Mercury and Electra receivers, provides communication with other ships and shore stations in all parts of the world. For emergency purposes an Alert guard receiver and a medium-wave Reliance transmitter, with automatic keying facilities, are also provided. The sound-reproducing and order system, also made by Marconi International Marine, feeds a network of 200 loudspeakers situated in passenger and crew spaces.

LIGHT AND DECORATION

Passenger accommodation on the Southern Cross is tourist class only, and passenger cabins are on the promenade, main, saloon, and A and B decks. The main public rooms are on the lounge deck, as shown in Fig. 2, and on the sun and sports decks there is ample room for deck games. The two restaurants on the saloon deck, one forward and one aft of the galley, seat respectively 390 and 192 people. On the lower deck is the indoor swimming pool, and on the sun deck is an open-air pool; both have changing rooms close by. Other public rooms are the recreation room, infants' play room and play deck, and childrens' play deck, all on the sun deck. There are also laundry, facilities, a hospital, a shop and hairdressing salons.

The lounge deck shows the good use that can be made of the space when propelling machinery is away from the centre of the ship. The four rooms—forward lounge, smoke room, cinema, and tavern—are decorated in contrasting styles, and the tavern and the lounge extend across the complete width of the ship.

The lounge extends the full width of the ship with windows along both sides and the forward end, fitted with venetian blinds in pastel blue and draped with full length curtains in a contemporary print. A series of slender pillars of satin-finished stainless steel, arranged in an ellipse, provide a separate area at the centre of the room, like a pavilion within the lounge itself. At night, the ceiling of this central area is illuminated from two floodlit bowls on bases of Nigerian walnut wood, in which the brilliant stars of the Southern Cross, carved from transparent plastic, are set like jewels. Inside the ring of pillars the deck is covered with a large oval hand-made carpet of deep pile, in colours of wine and white. The service bar at the after end is concealed by three screens, the upper parts of which consist of a series of glass panels, deeply sand-blasted and etched in designs depicting the bird life of Australia, New Zealand, and South Africa.

Abaft the lounge are the writing room at the port side and the library at the starboard side. The writing room, in which careful attention has been paid to suitable lighting, has room for 28. The library has room for three thousand books in glazed bookcases of white sycamore. The furnishings and decorations in the forward lounge, writing room, and library were done by Heaton Tabb and Company, Limited, who were also responsible for the decoration of the tavern, described later, the restaurants, and the stairs and hallways.

The smoke room, shown in Fig. 2. aft of the lounge, was decorated and furnished by Hampton and Sons, Limited. It has seating

accommodation for 154 people and the decorative treatment is modern in character. Silver grey elm veneers cut from the piles supporting the old Waterloo bridge have been used for the flush panelling, relieved by dark walnut skirting and trim. In three corners above the banquette seating are colourful murals of the arms of Australia, New Zealand and South Africa, executed in oils and enamels. The entrance doors at the forward and after ends of the room are partly screened to divide the flow of entrants and to obtain full use of the area immediately in way of the doors. The screens are open grilles in copper bronze above shaped settees. The circular raised ceiling housing the sprinkler and ventilation system is stepped up to a shallow dome in the centre and lit by concealed lighting. The banquette seating, almost continuous around the room, is in red Vaumol hide with grey piping and buttons, and the arm chairs, tub type chairs and easy chairs are in alternate arrangement of red, grey and chocolate.

The smoke room and the cinema lounge occupy the space that would be split up by machinery casing in a conventional passenger vessel. The cinema lounge was decorated and furnished by Maple and Company, Limited. It is furnished as a lounge and has a dance floor of 40 ft. by 25 ft. with raised side platforms. These sections are permanently furnished, but when the room is used for dancing the other furniture is removed and the space under the balcony is set out with smaller chairs and tables. The balcony at the forward end, which can be seen in Fig. 2, seats 117 passengers, and when used as a cinema or for concerts the lounge has a total seating capacity of about 435. The projection room is on the balcony, and the equipment of the large stage at the after end includes coloured batten lights and Gaumont British sound-production equipment. The main ceiling has indirect lighting and the bulkhead lights and fittings under the balcony are provided with pilot lights for use during stage performances.

Aft of the cinema lounge is the tavern, which, like the lounge, extends across the full width of the ship. It has a large bar at one side, a dance floor at the other, and the remainder of the room is filled with wooden settles reminiscent of a continental *bierkeller*. The general level of lighting has been kept low, but the bar is brightly lit, and the dance floor is lit by fittings recessed in the ceiling which can provide colour changes.

PASSENGER AND CREW CABINS

Out of a total of 1,160 passengers, 1,028 are accommodated in two-, four-, and six-berth cabins. The remainder are in single- and two-bedstead cabins with and without showers, and two-berth cabins with showers. The cabins have hot and cold running water and are fitted with all the amenities which add to the comfort of passengers during the voyage. Provision is made in each cabin for an electric razor. In all cabins without portholes an extra circuit has been incorporated into the lighting system to give the effect of sunrise. This comes into operation for about an hour each morning, dimly at first and gradually increasing in intensity without ever attaining the brilliance of the ordinary electric lighting of the room. Two shades of formica, blue and cream linette, have been used for the wall coverings of the rooms on alternate decks.

The Southern Cross carries a complement of 411 officers, petty officers and ratings, including 22 female staff. All officers and chief petty officers have single-berth cabins and all crew accommodation below the saloon deck is air-conditioned. Six separate air-conditioned messes are provided on A deck for the different grades of petty officers, seamen, firemen, and stewards, and another on the saloon deck for the female staff. There is a large crew recreation deck at the forward end of the promenade deck with a covered-in promenade immediately underneath. On the lower deck there is a spacious air-conditioned recreation room in which is installed a cinema apparatus for the crew.

Labour Notes

ENGINEERING WAGES INCREASED

For the first time for several years, a major claim for increased wages in the engineering and allied industries was settled last week at the first meeting to take place between representatives of the two sides after the submission of the original demand.

By the terms of the agreement, which was concluded between the Engineering and Allied Employers' National Federation and the Confederation of Shipbuilding and Engineering Unions on March 9, adult male employees in these industries were due to receive substantial increases in their basic rates of pay as from last Monday.

Skilled craftsmen will obtain an extra 11*s.* a week, labourers an additional 8*s.* a week, and semi-skilled men in the intermediate grades an increase of 9*s.* 6*d.* a week. In their original claim, which was presented to the employers' Federation on December 14, the unions asked for increases of 15*s.* a week on the basic rates for skilled men and of 10*s.* a week on those of unskilled employees. In addition, they proposed the setting up of a number of intermediate grades for semi-skilled operatives, in order that the varying abilities of these employees might be more adequately recognised than at present.

The unions' demands were based mainly on the contentions that there had been a considerable increase in productivity, that the industries were quite prosperous and that wages were not keeping pace with the cost of living.

DIFFERENTIAL MAINTAINED

Only firms affiliated to the employers' Federation are bound by the new agreement, but, as in the case of previous increases, it is reasonably certain that the great majority of other employers will give their men corresponding advances in their wages.

In one way and another, a total of well over two-and-a-half million men are expected to benefit from the increases to which the employers' Federation has already agreed. The cost to the employers, according to recent estimates, is likely to be about £65 to £70 millions a year.

The settlement is also likely to have a decided influence on the unions' claim for an additional £1 7*s.* 8*d.* a week for the 400,000 women engaged in the engineering group of industries. Juvenile employees will also benefit proportionately. The employers' Federation is due to reply to these claims on March 30.

A point of special interest about the settlement is that the percentage of the differential for skill will be largely maintained by the new basic time rates which amount to £7 15*s.* 10*d.* a week for craftsmen and £6 12*s.* 10*d.* a week for unskilled men.

MORE HOLIDAYS

Another concession granted by the employers' Federation was in respect to holiday arrangements. The industries' existing agreement will be amended in such a way as to provide that all employees with at least a year's service with any firm shall be entitled to two weeks' holiday with pay, in addition to the six recognised bank holidays. At present, these statutory holidays count as part of the fortnight.

A fairly lengthy discussion took place on the unions' proposals regarding improvements in the wage structure of the industries concerned. As stated above, the unions had suggested the establishment of some three or four semi-skilled grades to provide variations in rates of pay for men performing work requiring intermediate stages of skill and responsibility.

They are understood also to have in mind the setting up of a new grade of specially-skilled craftsmen, to whom an increased differential would be payable. To all these suggestions, the employers' Federation put forward proposals of their own.

It was eventually decided that, although improvements in the industries' wage structure were desirable, established practices could not be changed at short notice, and that changes, if any were to be made, should be introduced gradually.

One suggestion put forward was that committees containing representatives of the employers' Federation and of the Confederation of Shipbuilding and Engineering Unions should be formed to investigate the re-grading of engineering employees.

It was agreed that, in any event, discussions between the two sides on the question of the wage structure in this group of industries should continue.

MINERS' WAGE STRUCTURE

Agreement was reached a short time ago between the National Coal Board and the National Union of Mineworkers on the re-classification of the six thousand job names, by which the many hundreds of trades at British collieries have been known, into some 360 different categories of work and the task of dividing these specific jobs into different grades also appears to be completed.

Representatives of the two bodies held a further meeting on March 9 to begin negotiations on the rates of wages to be paid to day-wage men employed in each of the new grades. The magnitude of the problem and the closeness of the bargaining may be inferred from the fact that the discussions extended for some seven hours. The meeting then adjourned and it was announced that the miners' leaders would report to their executive committee.

PRINTING UNIONS AMALGAMATE

After some months of negotiations, ballots of the memberships of the London Society of Compositors and the Printing Machine Managers' Trade Society have been taken on the suggestion that there should be a merger of the two unions.

These ballots were completed a short time ago and have resulted in overwhelming majorities in favour of the proposal. In the case of the larger body, the L.S.C., there was a vote of 7,602 in favour against 932 in opposition.

The new joint organisation will have a total membership of around 15,000 and possess funds estimated to exceed £1 million. It will be known as the London Typographical Society.

DECLINE OF UNEMPLOYMENT

Statistics issued by the Ministry of Labour and National Service show that the number of persons in Great Britain in civil employment (industry, commerce and services of all kinds) at the end of January was 22,720,000, an increase of 10,000 since the end of December last.

The main changes were an increase in the manufacturing industries, in which the principal element was an increase in the metals, engineering and vehicle-building group, and decreases in the building and distributive trades.

Unemployment figures declined by 16,000 between January 10 and February 14; the number of persons registered as out of work on the latter date being 282,000, including 15,000 temporarily disengaged.

NOTICES OF MEETINGS

Association of Supervising Electrical Engineers

LONDON
Prize-Winning Papers, W. E. Highfield Shield Competition, 1954-55. "Magnetic Amplifiers," by D. H. Taylor; "The Evolution of Fluorescent Lighting Control Circuits," by G. V. McNeil; and "Photometric Curves and Some of Their Useful Applications," by H. G. Batson. Lighting Service Bureau, 2 Savoy-hill, W.C.2. Tues., Mar. 22, 6.30 p.m.

WEMBLEY
Discussion on "Industrial Switchgear and Circuit-Breakers." North-West London Branch. Century Hotel, Forty-avenue, Wembley Park. Fri., Mar. 25, 8.15 p.m.

Electrical Association for Women

LONDON
Tenth Caroline Haslett Trust Lecture on "Focus on Finland," by Miss M. J. Cumming. Institution of Electrical Engineers, Savoy-place, Victoria-embankment, W.C.2. Tues., Mar. 22, 6 p.m.

Illuminating Engineering Society

BATH
"Shop and Store Lighting," by R. L. C. Tate. Bath and Bristol Centre. Offices of the South Western Electricity Board, Old Bridge-street, Bath. Fri., Mar. 25, 7 p.m.

HULL
Address by H. G. Campbell. Leeds Centre. Offices of the Yorkshire Electricity Board, Ferensway, Hull. Mon., Mar. 21, 7.30 p.m.

Incorporated Plant Engineers

BIRMINGHAM
Annual General Meeting. Birmingham Branch. Imperial Hotel, Birmingham. Fri., Mar. 25, 7.30 p.m.

BLACKBURN
Annual General Meeting. Blackburn Branch. Golden Lion Hotel, Blackburn. Wed., Mar. 23, 7.30 p.m.

SHEFFIELD
Annual General Meeting. Sheffield Branch. Grand Hotel, Sheffield. Thurs., Mar. 24, 7.30 p.m.

Institute of British Foundrymen

NEWPORT
"Foundry Developments in the Textile Industry," by B. Gale. Wales and Monmouth Branch. Newport Technical College, Clarence-place, Newport, Monmouthshire. Sat., Mar. 26, 6 p.m.

NORTHAMPTON
"Patternmaking for Production Moulding," by S. A. Horton. Northampton Section. Plough Hotel, Northampton. Thurs., Mar. 24, 7.30 p.m.

NUNEATON
"Running and Feeding Methods for Light Alloys," by W. J. Sully. Birmingham Branch. Works of Sterling Metals, Ltd., Nuneaton. Wed., Mar. 23, 7.15 p.m.

SLOUGH
"Cylinder Casting," by A. Emmerson. Annual General Meeting. Slough Section. Offices of High Duty Alloys, Ltd., Slough. Tues., Mar. 22, 7.30 p.m.

Institute of Fuel

LONDON
"The Development and Use of the Calorimeter Building at the Fuel Research Station, Greenwich." Two papers, by W. F. B. Shaw and J. W. McHugo, respectively. Institution of Civil Engineers, Great George-street, S.W.1. Thurs., Mar. 24, 5.30 p.m.

GLASGOW
Annual General Meeting and Film Evening. Scottish Section. Royal Technical College, Glasgow. Fri., Mar. 25, 7 p.m.

STOKE-ON-TRENT
"Advances in Complete Gasification," by Dr. F. J. Dent. Midland Section. Offices of the Midlands Electricity Board, Kingsway, Stoke-on-Trent. Tues., Mar. 22, 7 p.m.

Institute of Marine Engineers

LONDON
Annual General Meeting. Education Group. Tues., Mar. 22, 5.30 p.m.

KINGSTON-UPON-HULL
"The Free-Piston Gas-Generator Turbine as a Power Plant for Ship Propulsion," by F. A. I. Muntz and Robert Huber. Kingston-upon-Hull and East Midlands Section. Royal Station Hotel, Kingston-upon-Hull. Thurs., Mar. 24, 7.30 p.m.

Institute of Marine Engineers and Institution of Naval Architects

SOUTHAMPTON
Annual General Meeting, at 7 p.m. "Prefabrication in Shipyards," by D. M. Kerr, at 7.30 p.m. Southern Joint Branch. Technical College, St. Mary-street, Southampton. Thurs., Mar. 24.

Institute of Metals

BIRMINGHAM
"Shielded Arc Welding," by Dr. E. C. Moore. Birmingham Local Section. James Watt Memorial Institute, Great Charles-street, Birmingham. Thurs., Mar. 24, 6.30 p.m.

SHEFFIELD
"Protection of Steelworks from Atmospheric Corrosion," by Dr. F. R. Himsworth. Sheffield Local Section. University Buildings, St. George's-square, Sheffield. Mon., Mar. 21, 7.30 p.m.

SWANSEA
Annual General Meeting and Film Evening. South Wales Local Section. University College, Singleton Park, Swansea. Tues., Mar. 22, 6.45 p.m.

Institute of Road Transport Engineers

DURHAM
Various short papers by members of the Group. North-East England Group. Royal County Hotel, Durham City. Tues., Mar. 22, 7 p.m.

Institute of Welding

LONDON
"Recent Achievements in Welding Research," by H. G. Taylor. North London Branch. Polytechnic, Regent-street, W.1. Thurs., Mar. 24, 7.30 p.m.

BIRMINGHAM
"Principles of Nozzle Design," by R. E. Jahn. Birmingham Branch. Birmingham and Midland Institute, Paradise-street, Birmingham. Fri., Mar. 25, 7.30 p.m.

Institution of Chemical Engineers

BIRMINGHAM
"The Role of the Student Section in the Training of the Chemical Engineer," by Professor F. Morton. Midlands Graduates' and Students' Section. The University, Edmund-street, Birmingham. Wed., Mar. 23, 6.30 p.m.

HUDDERSFIELD
"The Separation of Organic Mixtures by Solidification from the Melt," by J. S. Forsyth and J. Wood. North-Western Branch. Huddersfield Technical College, Huddersfield. Wed., Mar. 23, 7 p.m.

Institution of Civil Engineers

LONDON
"A Survey of Modern Concrete Technique," by E. E. H. Bate and D. A. Stewart. Works Engineering Division. Tues., Mar. 22, 5.30 p.m.

MANCHESTER
"The Influence of Site Conditions on the Design of Earth Dams," by J. B. Holt. North-Western Association. Engineers' Club, Albert-square, Manchester. Thurs., Mar. 24, 6.30 p.m.

NOTTINGHAM
"The Design and Construction of Gunthorpe Pipe Bridge," by A. J. Harris and C. J. Adamson. Midlands Association. Offices of the East Midlands Gas Board, Lower Parliament-street, Nottingham. Tues., Mar. 22, 6.30 p.m.

SHEFFIELD
"Scale Model Investigation of Hydraulic Engineers' Problems," by Dr. W. Eastwood. Yorkshire Association. Grand Hotel, Sheffield. Fri., Mar. 25, 7 p.m.

Institution of Electrical Engineers

LONDON
Discussion on "Materials for Valves," opened by Dr. O. Jenkins. Radio Section. Mon., Mar. 21, 5.30 p.m.
Discussion on "High-Voltage Equipment in Colleges," opened by Dipl. Ing. T. Siklos. Education Discussion Circle. Tues., Mar. 22, 6 p.m.
"Proving the Performance of Circuit-Breakers, with Particular Reference to Those of Large Breaking Capacity," by J. Christie, H. Leyburn and J. F. Bird; and "A New Testing Station for High-Power Circuit-Breakers," by J. Christie, H. Leyburn and R. W. Fenn. Supply Section. Wed., Mar. 23, 5.30 p.m.

CHELMSFORD
"The Taming of Graduates," by J. M. Armstrong. London Students' Section. District Meeting at the Public Library, Chelmsford. Tues., Mar. 22, 7 p.m.

CHESTER
"Current Summations with Current Transformers," by A. Hobson. Mersey and North Wales Centre. Town Hall, Chester. Mon., Mar. 21, 6.30 p.m.

DUNDEE
Faraday Lecture on "Courier to Carrier in Communications," by T. B. D. Terroni. Scottish Centre. Caird Hall, Dundee. Fri., Mar. 25, 7.30 p.m. (Admission by ticket.)

EDINBURGH
Faraday Lecture on "Courier to Carrier in Communications," by T. B. D. Terroni. Scottish Centre. Central Halls, Tollcross, Edinburgh. Tues., Mar. 22, 7.30 p.m. (Admission by ticket.)

WORKINGTON
"A Brushless Variable-Speed Induction Motor," by Dr. F. C. Williams and E. R. Laithwaite. North-Eastern Centre. District Meeting at the Workington Technical College, Workington. Fri., Mar. 25, 7 p.m.

Institution of Engineers and Shipbuilders in Scotland

GLASGOW
"Supercharging the Marine Diesel Engine," by P. Jackson. Tues., Mar. 22, 7.30 p.m.

Institution of Mechanical Engineers

LONDON
Discussion on "There is no Future in Great Britain for the Motor Scooter." Tues., Mar. 22, 6.45 p.m.
"Hydraulic Transport of Solids," by R. C. Worster and Dr. D. F. Denny. Fri., Mar. 25, 5.30 p.m.
"Investigation of Factors Determining the Refrigerating Capacity of a Diffusion-Absorption Refrigerator," by C. K. Gulland. London Graduates' Section. Wed., Mar. 23, 6.30 p. m.

BRIGHTON
"Back Pressure Generation," by Dr. A. R. Morcom. Southern Branch. Technical College, Brighton. Wed., Mar. 23, 7 p.m.

GLASGOW
"Heavy-Duty Truck Developments in the United States of America," by Robert Cass. Scottish A. D. Centre. Institution of Engineers and Shipbuilders in Scotland, 39 Elmbank-crescent, Glasgow. Mon., Mar. 21, 7.30 p.m.

LUTON
"Heavy-Duty Truck Developments in the United States of America," by Robert Cass. Luton A.D. Centre. Town Hall, Luton. Thurs., Mar. 24, 7.30 p.m.

NORWICH
"Production of a Technical Journal," by B. W. Pendred. Eastern Branch. Assembly House, Norwich. Thurs., Mar. 24, 7.30 p.m.

SHEFFIELD
Thomas Hawksley Lecture on "Recent Studies of Metallic Friction," by Dr. F. P. Bowden. Yorkshire Branch. The University, St. George's-square, Sheffield. Wed., Mar. 23, 6.30 p.m.

Institution of Production Engineers

LONDON
"Predetermined Time Standards," by J. E. Payne. London Graduate Section. Tues., Mar. 22, 7.15 p.m.

BRISTOL
"Motor-Car Manufacture at Vauxhall Motors Ltd.," by R. L. Blades. Western Section. Grand Hotel, Broad-street, Bristol. Wed., Mar. 23, 7.15 p.m.

MANCHESTER
"Manufacture of Commercial Vehicles," by A. Hooker. Manchester Section. College of Technology, Sackville-street, Manchester. Mon., Mar. 21, 7.15 p.m.

NEWCASTLE-UPON-TYNE
Brains Trust Meeting. North-Eastern Section. Neville Hall, Westgate-road, Newcastle-upon-Tyne. Mon., Mar. 21, 7 p.m.

Institution of the Rubber Industry

LIVERPOOL
"Manufacture and Design of Electric Cables," by W. A. Tandy and A. H. H. Young. Merseyside Section. 24 Hatton-garden, Liverpool. Mon., Mar. 21, 7 p.m.

MANCHESTER
"Ozone Resistance of Butyl Vulcanisates," by D. C. Edwards and E. B. Storey. Manchester Section. Engineers' Club, Albert-square, Manchester. Mon., Mar. 21, 6.45 p.m.

Institution of Water Engineers

LONDON
Annual General Meeting. "Modifications at Fleam Dyke Pumping Station, Cambridge University, and Town Waterworks Co.," by W. Grant Gibson; and "Features of the Design and Construction of the Hornsey Contact Tank, Metropolitan Water Board," by H. K. Davies and A. W. Turner. South-Eastern Section. Institution of Civil Engineers, Great George-street, S.W.1. Wed., Mar. 23, 2.30 p.m.

Junior Institution of Engineers

LONDON
"Amateur Telescope Making," by Dr. R. D. Gifford. Fri., Mar. 25, 7 p.m.

Manchester Association of Engineers

MANCHESTER
"Engineering Problems Associated with Production and Operations at Low Temperature," by H. E. Charlton. Annual General Meeting. Engineers' Club, Albert-square, Manchester. Fri., Mar. 25, 6.45 p.m.

Modular Society

LONDON
"Modular-Co-ordination Research," by W. A. Allen. Royal Society of Arts, John Adam-street, W.C.2. Wed., Mar. 23, 7.30 p.m.

North East Coast Institution of Engineers and Shipbuilders

NEWCASTLE-UPON-TYNE
"Geometrical Size Effect in Notch Brittle Fracture," by Dr. A. A. Wells. Neville Hall, Westgate-road, Newcastle-upon-Tyne. Fri., Mar. 25, 6.15 p.m.

Reinforced Concrete Association

GLASGOW
"Reinforced Concrete in Coast-Protection Works," by J. A. Lewis. Royal Technical College, Glasgow. Tues., Mar. 22, 6.30 p.m.

Royal Aeronautical Society

LONDON
"Analogue Computing Applied to Aeronautical Problems," by K. V. Diprose. Institution of Mechanical Engineers, 1 Birdcage-walk, S.W.1. Thurs., Mar. 24, 6 p.m.

Royal Institution

LONDON
"A Century of Aluminium," by George Boex. Fri., Mar. 25, 9 p.m.

Royal Society of Arts

LONDON
"Mechanical Properties of Metals. II—Creep," by Professor E. N. da C. Andrade. Mon., Mar. 21, 6 p.m.
"Radio Astronomy," by Professor A. C. B. Lovell. Wed., Mar. 23, 2.30 p.m.

Sheffield Metallurgical Association

SHEFFIELD
Discussion on "Open-Hearth Furnaces: Casting Pit." B.I.S.R.A. Laboratories, Hoyle-street, Sheffield. Tues., Mar. 22, 7 p.m.

Société des Ingénieurs Civils de France (British Section)

LONDON
"Foundations: Practical Problems in Design and Construction," by F. S. Snow. Institution of Civil Engineers, Great George-street, S.W.1. Mon., Mar. 21, 5.30 p.m.

Women's Engineering Society

LONDON
"Oxygen Breathing Apparatus," by P. W. Fitt. Mon., Mar. 21, 7 p.m.

The address and telephone number of the headquarters of each institution are given below. Meetings in the headquarters town are held there unless otherwise stated. Particulars for this column should reach the Editor not later than Monday morning in the week preceding the date of the meeting.

Association of Supervising Electrical Engineers, 23 Bloomsbury-square, London, W.C.1. (LANgham 5927.)
Electrical Association for Women, 35 Grosvenor-place, London, S.W.1. (SLOane 0401.)
Illuminating Engineering Society, 32 Victoria-street, London, S.W.1. (ABBey 5215.)
Incorporated Plant Engineers, 48 Drury-lane, Solihull, Birmingham. (Solihull 3021.)
Institute of British Foundrymen, St. John Street Chambers, Deansgate, Manchester 3. (Blackfriars 6178.)
Institute of Fuel, 18 Devonshire-street, Portland-place, London, W.1. (LANgham 7124.)
Institute of Marine Engineers, 85 The Minories, London, E.C.3. (ROYal 8493.)
Institute of Metals, 4 Grosvenor-gardens, London, S.W.1. (SLOane 6233.)
Institute of Road Transport Engineers, 69 Victoria-street, London, S.W.1. (ABBey 6248.)
Institute of Welding, 2 Buckingham Palace-gardens, London, S.W.1. (SLOane 9851.)
Institution of Chemical Engineers, 56 Victoria-street, London, S.W.1. (VICtoria 6161.)
Institution of Civil Engineers, Great George-street, London, S.W.1. (WHItehall 4577.)
Institution of Electrical Engineers, Savoy-place, Victoria-embankment, London, W.C.2. (TEMple Bar 7676.)
Institution of Engineers and Shipbuilders in Scotland, 39 Elmbank-crescent, Glasgow, C.2. (Central 5181.)
Institution of Mechanical Engineers, 1 Birdcage-walk, St. James's Park, London, S.W.1. (WHItehall 7476.)
Institution of Naval Architects, 10 Upper Belgrave-street, London, S.W.1. (SLOane 4622.)
Institution of Production Engineers, 10 Chesterfield-street, London, W.1. (GROsvenor 5254.)
Institution of the Rubber Industry, 12 Whitehall, London, S.W.1. (WHItehall 5012.)
Institution of Water Engineers, Parliament Mansions, Abbey Orchard-street, London, S.W.1. (ABBey 6740.)
Junior Institution of Engineers, Pepys House, 14 Rochester-row, London, S.W.1. (VICtoria 0786.)
Manchester Association of Engineers, 20 Booth-street, Manchester 2. (Central 2796.)
Modular Society, 22 Buckingham-street, London, W.C.2. (TRAfalgar 4567.)
North East Coast Institution of Engineers and Shipbuilders, Bolbec Hall, Newcastle-upon-Tyne 1. (Newcastle 20289.)
Reinforced Concrete Association, 94-98 Petty France, London, S.W.1. (ABBey 4504.)
Royal Aeronautical Society, 4 Hamilton-place, London, W.1. (GROsvenor 3515.)
Royal Institution, 21 Albemarle-street, London, W.1. (HYDe Park 0669.)
Royal Society of Arts, John Adam-street, Adelphi, London, W.C.2. (TRAfalgar 2366.)
Sheffield Metallurgical Association, 15 Crescent-road, Sheffield 7. (Sheffield 53674.)
Société des Ingénieurs Civils de France (British Section), 82 Victoria-street, London, S.W.1. (VICtoria 6838.)
Women's Engineering Society, 35 Grosvenor-place, London, S.W.1. (SLOane 0401.)